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PUBLIC SERVICE USER TERMINUS STUDY

COMPENDIUM OF TERMINUS EQUIPMENT

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BY:

EDUTEL
COMMUNICATIONS AND DEVELOPMENT, INC.
701 WELCH ROAD • SUITE 225 • PALO ALTO • CALIFORNIA 94304 • 415/328/4972

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF FIGURES AND TABLES

LIST OF FIGURES AND TABLES (continued)

LIST OF FIGURES AND TABLES (continued)

LIST OF FIGURES AND TABLES (continued)

1. INTRODUCTION AND BACKGROUND

Since the beginning of this decade, extensive experimentation in satellite and terrestrial communications systems for public services has been underway. In March 1978, NASA issued a Request for Information (RFI) to all commercial communication carriers requesting them to propose costs for the delivery of a number of specified public services. The responses, in many instances, were extensive and complete, representing a substantial effort and providing valuable information. It appeared, however, that more information was needed for the purposes of public service agencies, mainly dealing with the costs of service, geographic coverage, and user terminus equipment now available or likely to become available by the early 1980's.

This compendium is the result of a contract written to provide more complete cost and availability data on several categories of user terminus equipment. For the purpose of this study, the term "user terminus equipment" means equipment which acts as the interface between a human, mechanical, or electrical information generator or source and a communications system. The terminus equipment thus operates at base-band on inputs and outputs that consist of voice/audio, visual images or scenes, raw binary data (i.e., voltages representing 1's and 0's), and printed media. The study is not intended to cover such equipment as radios, antennas, and other parts of the communications transmission and reception system. Some material is included on PABX equipment in one category and computers in another category, although neither of these are considered to be terminus equipment. The discussion on these equipments is included for completeness and to give a better understanding of the manner in which the terminus equipment integrates into the overall system.

1.1 PURPOSE.

This compendium is assembled to facilitate the construction and detailed analysis of various satellite and terrestrial communications delivery systems models which will include user-to-user service.

These models will be used to design communications networks in which key components may be changed and compared to allow economic trade-offs to be made between user costs and service. It also may be used by public service user agencies seeking information on cost, availability, and sources of terminus equipment.

In addition to equipment and system descriptions and costs, this compendium includes other material of interest to the public service user of the equipment, namely information on quality, reliability, limitations, interface parameters, and any special requirements or precautions. The user should be aware that, while every effort was made to achieve completeness and accuracy, rapid changes in equipment technology and costs make it well worthwhile to contact vendors for the most up-to-date cost and performance information.

1.2 ARRANGEMENT OF THE COMPENDIUM.

This compendium has been arranged into four major equipment categories as follows:

- Voice/Telephony/Facsimile
- Data/Graphics Interchange
- Video Equipment
- Multiple Access Equipment

A perusal of the Table of Contents will reveal these four major headings, and the specific types of equipment may be located within each category.

Each type of equipment in each category is covered in the same format. First, a general description of the equipment and its characteristics, limitations, and any special or notable qualities is presented. In this section also will be found three sets of tables. The first table presents typical, or average, specifications of the equipment. These specifications may be from various industry or regulatory standards or from a representative piece or group of equipment. They are intended to show how the equipment is usually specified, what is important, and what to look for. The descriptive text explains specification terms that are not self-explanatory or that are not widely understood. The user may not find one single piece of equipment that meets all of these specifications.

The second table in each section is a listing of many of the most prominent suppliers and their equipment by model. If the specifications warrant, this table also lists a number of characteristics that are the most important to the user, and that may vary from one equipment to another. From this table, the user can get some idea of the price range that the equipment covers and what equipment differences may cause the price variations. In the competitive industrial environment of today, it is usually safe to assume that large price differences result from large differences in performance or quality.

The third table is a listing of major vendors, manufacturers, and suppliers of the equipment category along with their addresses and telephone numbers. The list may not be exhaustive, but it usually is extensive and covers companies making the particular equipment discussed and not just peripherally involved because of nomenclature. There may be companies listed in this table whose equipment is not included in the previous table. Most addresses and phone numbers are main headquarters locations. The inquiring user may be referred to a local or regional representative or office when calling this number.

The user is cautioned in making use of some of the pricing information in this compendium. For the most part, companies and representatives contacted were cooperative and supplied as much information as possible. Some types of equipment, such as PABX's, computers, and multiple access/multiplex equipment are almost impossible to price with any accuracy in the absence of a specific requirement and application. Companies supplying prices for these equipment types usually did so with some misgivings as to meaningful interpretation and comparison. Therefore, the user is urged to contact vendors with his specific requirements for the most accurate price and performance information.

The second section of each equipment category discusses the future trends for this type of equipment. This discussion covers new developments now coming out and other equipment likely to become available by the early 1980's.

2. VOICE/TELEPHONY/FACSIMILE EQUIPMENT

This section of the NASA terminus study provides information on the prime category which includes the following major equipment types:

- Voice/telephony
- Facsimile
- Radiotelephone (Phonepatch)

The voice/telephony category is quite all-inclusive, and we have interpreted this nomenclature to mean just about any type of equipment that might be used as the initial input or final output of any public service communications or information distribution link. This type of equipment, then, operates at baseband and can be used in a classroom with many listeners, in some sort of private residence with only one listener per location, or even in voice recording situations where tapes might be mailed or carried to the ultimate user. As such, this category includes the following equipment:

- PABX Equipment
- Telephones
- Speaker phones
- Specialized Equipment such as Answering Machines or Automatic Dialup
- Speakers
- Microphones
- Amplifiers (Audio)
- Tape Recorders (AM-FM Baseband)
- Patch Panels

Facsimile equipment includes items used for the transmission of hard copy at baseband or voice band frequencies. Radiotelephone or phonepatch equipment is used in mobile(mainly vehicular) radio where the link is partially by radio (HF, VHF or UHF) and partially over standard telephone lines. Phonepatch, in particular, is used predominantly by amateur radio operators, where the so-called "ham band" is used for the long-range link and the final leg is patched into the telephone lines by the ham operator at the receiving and/or sending end. Subscriber loop radio also is in this category, except that now the long-distance link probably is over telephone lines, and the subscriber loop radio takes over at a switching center and completes the link to the individual user.

2.1 TELEPHONY AND PABX EQUIPMENT.

2.1.1 General Description and Specifications

Since regulatory action some years ago which allowed a user to connect his own telephone equipment to Bell System or other carriers' lines, a great proliferation of telephone equipment has occurred. The action had the desired effect, however, in that prices generally are quite competitive for similar equipment and specifications. The equipment listed in the tables in this section is intended to be representative in type and price rather than to cover every device and instrument on the market. No preference or endorsement of one manufacturer's equipment over another's is intended or implied.

2.1.1.1 PABX Equipment: A great many types of telephony equipment are available at this time. In order to organize this wide variety of equipment and applications on a coherent and manageable basis, we have selected the PABX as the basic terminus system in telephony service. The PABX is the final switching center in a telephone network before the call reaches the end user. Extensions of the PABX or inputs to it are equipments such as the telephone instrument itself, speaker phones, and the various automatic or labor-saving attachments on the market.

The PABX is basically a telephone switch with widely varying numbers of lines into and trunks out of the switch. More sophisticated PABX's available today include additional capabilities such as station hunting; i.e., routing a call to the first idle station of a prearranged group if the first station is busy, line lockout (automatic line release after failure to dial), trunk route selection, toll restriction, intercept, and night answer. The PABX package and capability can vary from a front-office call director to a large DDD switch using digital techniques. Lines in (i.e., number of telephones attached) can vary from two to 25,000, or essentially an unlimited number, using modular techniques. Outbound trunks vary in number from one to about 4,800.

Telephone switches, of course, affect the quality of transmission on an analog network and, therefore, are controlled by specifications such as those put forth by CCITT Recommendation Q.45 (for international usage).(1) These specifications are shown in Table 2.1-1.

Telephone switch systems (PABX)(2) can be either digital or analog. The analog type operates directly on voice while the digital types use sampling techniques and Pulse-Code-Modulation (PCM). In addition, either type is available using stored program software control of call processing. There are several signaling techniques, such as in-band, out-of-band, dial tone multifrequency (DTMF), E&M, and common channel signaling. PABX systems must operate with signaling techniques that are compatible with the telephone network on the trunk lines. Some typical PABX systems are shown in Table 2.1-2. There are many more suppliers, both domestic and foreign. Each of them supplies PABX equipment at most of the above capacities and more. Table 2.1-4 is a listing of major suppliers of this equipment and their addresses; the list is not exhaustive.

Pricing of PABX equipment, as with several other types of equipment in this compendium, is difficult to present in a meaningful manner because of the many variations and configurations possible, depending on customer requirements. Prices shown are rough estimates given by the companies named. The user is advised to be cautious in making comparisons, and he/she should contact the companies with a set of specific requirements to get more exact pricing. Prices given, even on a per line basis, are not necessarily comparable to another switch with a different number of lines.

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(1) CCITT = Comite Consultif International Téléphone Telegraph, a consultative committee under the International Telecommunication Union (ITU).

(2) PABX = Private Automatic Branch Exchange.

Table 2.1-1

Telephone Switch Transmission Characteristics
(Four-Wire Switching)

Impedance	
Line	600 ohms
4-wire Trunk	600 ohms
Insertion Loss	0.5 dB
Dispersion Loss (Variation in loss from calls with highest loss to calls with lowest loss)	< 0.2 dB
Attenuation/Frequency Response	
300-400 Hz	-0.2/+0.5 dB
400-2400 Hz	-0.2/+0.3 dB
2400-3400 Hz	-0.2/+0.5 dB
Impulse Noise	5 in 5 minimum above -35 dBm0
Noise	
Weighted	200 pWp
Unweighted	1,000,000 pW
Unbalance against ground	
300-600 Hz	40 dB
600-3400 Hz	46 dB
Crosstalk	
Between go and return path	60 dB
Between any two paths	70 dB
Harmonic Distortion*	
2nd harmonic	-40 dB below fundamental at 1000 Hz
3rd harmonic	-40 dB below fundamental at 1000 Hz
Total	$\leq$ 1%
Envelope Delay*	
400-3200 Hz	475 $\pm$ 20 μsec
600-3000 Hz	340 $\pm$ 20 μsec
Echo Return Loss*	
Line-to-line	$\geq$ 25 dB
Line-to-trunk w/o pad	$\geq$ 25 dB
Trunk-to-trunk	$\geq$ 25 dB

*Typical values — not in CCITT Q.45

Table 2.1-2

PABX Equipment

Manufacturer	Model	Maximum Lines	Maximum Trunks	Budgetary Price
Western Electric	558A	40	10	sold only to AT&T
Wescom	580	2304	516	not available
Rolm	SCBX	144	40	$1K/line
Western Electric	756A	60	16	sold only to AT&T
Information Dynamics Group	IDX-230	30	10	$5-7.5K
GTE-Automatic Electric	GTD-120	120	28 (Digital)	not available
ITT	TD100	100	24	$175/line
Northern Telecom, Inc.	DMS-10	9600	2400	not available

2.1.1.2 Telephone Instruments and Ancillary Equipment.

The telephone instrument is composed of a transmitter, receiver, ringer, switchhook, rotary dial or pushbuttons, and an electrical transmission network to separate the transmitter and receiver circuits. The telephone set provides full duplex (simultaneous transmission and reception) operation over a two-wire circuit.

Two types of dialing are in wide use today in telephony systems. The rotary dial type opens and closes contacts as it turns back to its stop position, generating a train of DC pulses corresponding to the number of the selected digit. These pulsed digits are used to position switches in the automatic central office. Pushbutton dialing uses multifrequency tone keying to send AC pulses to the central office or other associated equipment, such as a computer. Services of this sort are not possible with the rotary dial since the DC pulses control only central office equipment. Pushbutton or keypad tones are in the voice frequency range and can be transmitted anywhere in the telephone network. Eight frequencies in the 700- to 1700-Hz range comprise the four-by-four code designed for pushbutton dialing. Pressing each pushbutton generates two tones, a high-band and a low-band frequency.

The telephone handset operates through a direct two-wire line to the central office. When the handset is lifted to originate a call, contacts on the switchhook close relays in the central office that indicate that a call is about to be initiated. In addition, relays in the central office mark the calling line's position on switch banks, start a line-finder selector hunting for the calling line, and send a busy signal to other calls. Switches and relays in the central office are set by the dialing action, and eventually the central office sends a ringing voltage to the called line.

Other ancillary equipment is available on the market to extend the usefulness of the telephone instrument itself. Such equipment includes automatic dialup and answering machines, speakerphones and wireless telephone extensions. These latter sets operate at 1.665-1.785 MHz and 49.83-49.89 MHz to allow cordless operation of a portable handset up to 300 feet or so from a base transponder at the telephone connection.

A basic telephone instrument with ringer markets for about $35 at present. Since regulatory action allowing customers to connect their own instruments to Bell System lines occurred, a wide variety of styles and prices have become available ranging up to several hundred dollars per instrument. Answering machines and automatic dialup equipment on the market are priced in the $200 to $300 range. Low-cost adaptors to four-pin wall jacks are needed with this equipment. Wireless telephone extensions are priced from $300 to $500. Speakerphones installed by the Bell System have a small installation charge and a monthly rate. Representative equipment types are shown in Table 2.1-3. Suppliers of telephony equipment are marked with an asterisk in the list of PABX suppliers in Table 2.1-4.

2.1.2 Future Developments in PABX and DAMA Products

PABX evolution is being driven by technology and market developments. The market for PABXs has grown rapidly in the past few years. In the U.S., the legitimazation of the interconnect market has led to a much greater interest on the part of corporations in better and more flexible communications services. Consequently, many more PABXs are being sold. Outside the U.S., especially in countries that are successfully developing such as Taiwan and Korea, the number of telephone lines installed and the number of switches needed has been growing rapidly. Often, modern electronic PABXs can be used for public telephone switches. Consequently, there is a large market incentive for companies to enter the PABX field.

Electronic technology has reached the point that many circuits used for building computers can also be used for building telephone switches. The application of microprocessors, LSI memories, and integrated solid-state crosspoint arrays to telephone switches has had technical impacts which, joined together with the growth of the market, create a near revolution in the cost and performance of PABXs. The developments will continue.

For purposes of discussing the technology involved in PABXs, the PABX functions may be divided into three categories: switching, control, and line interface. Several years ago all of these functions contributed equally to the cost of telephone switches. However, now

Table 2.1-3

Voice/Telephony Equipment

Equipment Type	Manufacturer	Model No.	Use	Price	Comments
Standard Telephone	Northern Telcom	NT600WD	Office-home	$22	Dial
" "	" "	NT600WT	" "	$50	Touch-tone
Telephone Answering Machine	Sanyo	TRA9907	Automatic Telephone Answering	$250	Voice-activated
Telephone Answering Machine	Sanyo	TRA9908	"	$495	Remote monitoring
"	Sanyo	M139N	"	$125	Receives & gives messages
Multiline Telephone	GTE-Automatic Electric	Type 187 (rotary)	Office	$59	3 lines + hold button
" "	"	Type 186 (rotary)	Office	$68	5 lines + 1 hold. Use with keysystem or intercom
" "	"	Type 102A	Office	$90	Keyset - 9 lines + 1 hold
Speakerphone	"	Type 882-A	Office	$190	10 & 16 button models Use with keysystem or intercom
Speaker set	"	417601 428197	Office	$165	Converts regular telephone to speakerphone (T/R)
Headset	"	HS0108-1-B	PABX,operator, switchboard	$65	Lightweight - background noise reduction
Desk Telephone	"	80E (rotary)	Office	$21	Standard
Speaker Telephone	"	881A	Office	$168	Standard

Table 2.1-4

Major Suppliers of PABX & Telephony Equipment

GTE-Automatic Electric, Inc.*
Communications Systems Division
400 North Wolf Road
Northlake, Illinois 60164
321-681-7100

ITT Telecommunications Division*
Electronic Switching Center
2000 South Wolf Road
Des Plaines, Illinois 60018
312-297-5320

Northern Telecom, Inc.*
2 International Plaza
Nashville, Tennessee 37217
615-361-3500

Wescom Switching, Inc.
P.O. Box 1458
Downers Grove, Illinois 60515
312-654-3680

Digital Telephone Systems, Inc.
A Farinon Company
1 Commerce Blvd.
P.O. Box 1188
Novato, CA 94947
415-472-2500

TRW Vidar
77 Ortega Ave.
Mountain View, CA 94040
415-961-1000

NEC America, Inc.
Teleco Division
1499 Regal Row
Dallas, Texas 75247
214-688-1600

Western Electric Co., Inc.*
(manufacturing unit of the
Bell System). Contact local
Bell System operating company
marketing or commercial
department.

Information Dynamics Corp.
1251 Exchange Drive
Richardson, Texas 75081
214-783-8090

Rolm Corp.
Dept. G
4800 Old Ironsides Drive
Santa Clara, CA 95050
408-988-2900

Siemens Corp.
Telephone Division
186 Wood Avenue South
Iselin, NJ 08830
201-494-1000

Stromberg-Carlson Corp.
Subsidiary of General Dynamics Corp.
100 Carlson Road
Rochester, NY 14603
716-482-2200

Sanyo Electric
51 Joseph Street
Moonachie, NJ 07074
201-641-2333

the switching and the control are done with low-cost, high-volume LSI units, and the major portion of the switch cost is the line interface. (This is expensive because the line interface must perform any analog-to-digital conversions, filtering, and supply high voltages for ringing.)

Because computer circuits can be used in PABXs, the cost of expanding the control and switching functions of a switch are very low. Consequently, modern PABXs offer a very wide range of services without much increase in cost. This trend will be accentuated in the future, and nearly any service that people might find useful will be provided by the switch. For example, switches are now being designed that will switch both voice and data traffic simultaneously—sometimes over the same pair of wires. Indicative of the ubiquity of computer technology in modern switches is the entry of Rolm, a minicomputer manufacturer, into PABX production. Western Electric has started production of 64K RAM memory chips for telephone switches.

Continuing advances in silicon technology will reduce the costs of the line interface functions through increasing circuit density and production volume. The long-run outlook is for a decline of switch costs as measured in constant dollars. Competition will largely focus on service and features including self monitoring and maintenance. Future PABXs may switch data as well as voice, and may be able to concentrate speakers on trunks by taking advantage of the speech activity factor or by sophisticated coding.

Partly to try to reduce the cost of signaling and partly to allow expanded services, AT&T formulated a new standard for signaling between telephone central offices. This new standard in the United States is called CCIS, which stands for Common Channel Inter-office Signaling. CCIS signaling uses a dedicated digital channel between two switches to transfer telephone signaling information (calling number, called number, busy, etc.) directly between the computer-based switch controller. All old standards used analog signals on <u>each trunk</u> connecting the switches, and was more expensive and less flexible. This mode of signaling should soon be used in PABXs for the connection between the PABX and the local telephone office to which the PABX is attached. In addition, CCIS signaling will allow PABX switches to be interconnected so that they can coordinate their functioning and be used in sophisticated private networks.

As the architecture of electronic switches follows the architecture of computers, there may be an increasing development of "distributed switching" similar in concept to distributed computation. Distributed telephone switches located at various places in a large building or industrial area will communicate with each other over broadband digital paths such as coaxial cables or optical fibers to share the switching load and reduce the costs associated with stringing many pairs of wire.

As one of the services that has been provided on the PABX, automated maintenance will increasingly reduce the problems of servicing telephone equipment. Microprocessor-based automatic maintenance and monitoring routines will allow manufacturers to provide unsophisticated users with PABXs which will have very little down time.

In the telephone instruments themselves, two developments are taking place. One is the electronic telephone. ITT and others are experimenting with a telephone instrument in which all of the electromechanical features will be replaced by electronic circuitry. This, of course, opens the door to applications of VLSI circuitry, microprocessors, and digital techniques. An extension of this technology will be the home terminal, which will be a combination of telephone, television, and computer capabilities.

The other development is the use of fiber optics in the transmission facilities themselves and the impact that this technology will have on the telephone instrument. The combination of fiber optics and the electronic telephone means that light energy may be used to power the telephone instrument and perform the ringdown function as well as carry the message itself.

These developments, coupled with more sophisticated PABXs, key systems, and automatic dialers and answering machines, indicate that telephone instrument development is by no means a static field.

2.2 MICROPHONES

2.2.1 General Description and Specifications

The microphone is used in the context of interest as the audio input for a voice return link in an interactive system. Any of the radio transmission gear discussed in this report includes a microphone for voice input. Like most equipment, microphones vary widely in cost and quality. Each type possesses characteristics which make it particularly suited to specific applications.

Microphones are classified according to use, i.e., program and announcing, speech, and public address/paging. Other important parameters are the directional characteristic, effective output level and impedance, and the hum pick-up level. The frequency response of a microphone must be as good as or better than the system with which it is used, for obvious reasons. Microphones which show impedance variations with frequency will have their response characteristics adversely affected by resistance loading at the input transformer to which they are connected. Therefore, many microphones are designed to work into a microphone preamplifier equipped with an unloaded input transformer to minimize the need for precise impedance matching. Microphones in which the moving system is highly damped have their frequency response little affected by electrical loading.

When a microphone connects to an unloaded transformer, its power output cannot be expressed in dBm since the microphone delivers no appreciable power. In these cases, the output level is expressed by a parameter known as the Effective Output Level. Another way in which this level is expressed is the EIA[1] standard rating known as G_M. Either the EIA rating computation or the Effective Output Level is based on the nominal source impedance of the microphone and on the sound pressure (in dynes / cm^2) applied to the microphone. These output parameters are expressed relative to an electrical reference level, such as 0.001 watt. The output rating can be combined with the conventional amplifier gain to give an output level.

(1) EIA - Electronic Industries Association.

The mounting of a microphone is important in order to keep low frequency "rumble" and microphonics to a minimum. Microphones are usually sold without the connecting plug, so that the proper plug may be selected by the user. Output transformers should be shielded to minimize hum. An adequate mounting is important for reliability and maintenance reasons, also.

The term "dynamic" in the description of a microphone indicates that the instrument generates a voltage internally from the incident sound waves, as opposed to "static" which indicates that the instrument operates by changing a resistance. Most high quality radio and public address microphones are of the dynamic variety. Ribbon types use a vibrating metal ribbon in a magnetic field to generate the output.

Table 2.2-1 presents general specifications for a representative microphone type. Microphone specifications often include a polar plot showing the directivity of the instrument. Table 2.2-2 presents specifications and prices of a number of microphone types. Table 2.2-3 lists major suppliers of microphones.

2.2.2 Future Trends

Most work in microphone development now is going in the direction of miniaturization. Materials research in transducers can be expected to produce very tiny, rugged microphones with extremely wide frequency response and dynamic range.

Table 2.2-1

Microphone Specifications
(RCA BK-5)

Use	Program, Announcing
Directional Characteristic	Improved Cardiod
Effective Output Level	-56 dBm G_m = -151 dB
Output Impedance	30/150 250 ohms
Frequency Response	30-20000 H_z
Max. Hum Pickup Level	-128 dBm rel. to hum field of 10^{-3} gauss.
Stand	Boom, Desk, Floor

Table 2.2-2

Studio Quality Microphones

Manu-facturer	Model	Type	Directivity	Frequency Response Hz	Output Impedence ohms	Effective Open Circuit Output Level @ Sound Pressure 10 dynes/cm^2 @ 1 KHz. Ref. .001 watt. (dB)	Price (w/o stand)
Sony	ECM-50PS	Electret Condenser	omni	40-14000	250	-79	$200
	ECM-170A	"	"	20-16000	200	-79	72
	ECM-210M	"	uni	50-12000	200	-79	30
	ECM-150	"	omni	40-13000	250	-80	65
	ECM-23F	"	uni	20-20000	250	-80	100
	F-27	Dynamic	uni	80-12000	320	-	15
	F-540	"	uni	80-13000	300	-83	42
	F-500	"	uni	80-12000	320	-83	21
RCA	77-0X	Ribbon	Poly	30-20000	30/150/250	-53	252
	BK-1	Pressure	Non	60-10000		-52	95
	BK-5	Ribbon	Impr. Cardiod	30-20000		-56	172
	BK-6	Miniature Dynamic	Semi	60-15000		-65	95
	BK-11	Ribbon	Bi	20-20000		-56	110
	BK-12	Subminiature Dynamic	Non	60-18000	30 to 250	-60	90

Table 2.2-2 (continued)

Manu-facturer	Model	Type	Directivity	Frequency Response Hz	Output Impedence ohms	Effective Open Circuit Output Level @ Sound Pressure 10 dynes/cm^2 @ 1 KHz Ref. ,001 watt (dB)	Price (w/o stand)	
RCA	BK-14	Dynamic	Omni	40-20000	30 to 250	-60	$149	$149
	BK-16	Dynamic	Omni	40-20000		-60	139	$139
	SK-30	Dynamic	Omni	50-14000		-55	22	$22
	SK-39	Aerodynamic	Semi	70-10000	250	-54	28	$28
	SK-46	Ribbon	Bi	40-15000	200/15000	-58	84	$84
Realistic (Radio Shack)	21-1172	Hand-held Dynamic	-	-	-	-	10	$10
Electro-voice	RE-10	Cardiod	-	-	-	-	120	$120
	635A	Dynamic	-	-	-	-	66	$66

Table 2.2-3

Microphone Suppliers

RCA Broadcast Systems Front and Cooper Streets Camden, NJ 08102 609-963-8000	Altec Sound Products Division 1515 S. Manchester Dr. Anaheim, CA 92803 714-774-2900
Sony Video Products Co. 9 West 57th Street New York, NY 10019 212-371-5800	Shure Brothers, Inc. 222 Harley Ave. Evanston, Ill. 60204 312-866-2200
Harris Corporation Broadcast Products Division P.O. Box 290 Quincy, Ill. 62301 217-222-8200	Electro Voice, Inc. Subsidiary of Gulton Industries 600 Cecil St. Buchanan, MI. 49107 616-695-6831
Lear Siegler, Inc. Bogen Division Rt.4 and Forest Ave. Paramus, NJ 07652 201-343-5700	Sennheiser Electronic Corp.(NY) 10 W. 37th St New York, NY 10018 212-239-0190
Radio Shack Division of Tandy Corporation P.O. Box 2625 Ft. Worth, TX 76101 (817) 390-3011	

2.3 SPEAKERS AND ENCLOSURES

2.3.1 General Description and Specifications

The counterpart to the microphone in audio transducers is the speaker. Here again, speakers range in cost and performance from the small car radio type to large hi-fidelity types employing acoustic suspension and other new techniques. Speakers are available in cabinets and enclosuresdesigned to enhance the sound quality of a stereo or professional sound system, and also as ruggedized designs for outdoor paging and sound reproduction.

If speakers are to be used in a room or auditorium, considerable effort can be expended in properly selecting and locating speakers for optimum sound reproduction in the room. The dispersion angle or angle over which the speaker projects sound most efficiently is taken into account along with room size and shape. The two most often quoted speaker parameters are frequency response and program power handling capability. Speakers usually are designed with either 4, 8, or 16 ohm inputs which must be matched to audio amplifier output impedance for maximum efficiency. Another characteristic is the sound pressure level (SPL) measured at a given distance from the speaker for a given power input. This parameter shows the efficiency of the speaker in converting electrical power into acoustic power. The weight of the magnet in the speaker is critical and much effort has gone into reducing the weight of this magnet while maintaining efficiency and low distortion.

Since speakers have a fairly definite frequency range over which they operate best, combinations of different size speakers are used in most high fidelity applications. Bass speakers, or woofers, plus mid-range speakers, and high frequency horns, or tweeters are carefully combined to provide a smooth, wide frequency response. Crossover frequency is the term used to describe the frequency at which the sound changes from one speaker to the next in such combinations.

The efficiency of a speaker is important in determining the power of the amplifier required to drive it and in selecting the proper size and type of speaker for a given room. Sound pressure level (SPL) is a measure of speaker efficiency, and it is usually given in dB above some reference sound level, usually .0002 dynes/cm^2. Thus, a SPL of 92 dB at 4 feet from an 8-inch speaker with an input of 1 watt means that the sound pressure is 31.7 x 10^4 dynes/cm^2 at a distance of four feet from the speaker. This is equivalent to a sound intensity of 1.58 x 10^{-7} watts/cm^2 at a distance of four feet from the speaker. With a speaker dispersion angle of 60°, total sound power four feet away is approximately 2.5 milliwatts. Most speakers of conventional design are quite inefficient devices, and this must be taken into account when selecting an amplifier. For low efficiency cone speakers, an efficiency of about 1% or less is not uncommon. Most conventional speakers require installation in an enclosure of several cubic feet volume for optimum operation.

Table 2.3-1 shows a set of specifications for a very wide dispersion angle speaker. Table 2.3-2 gives specifications of several hi-fidelity stereo-type speaker enclosures on the market. Several lower cost and outdoor speakers as well as studio quality speakers are also included. Table 2.3-3 list speaker manufacturers, both for high quality consumer types and professional studio types.

2.3.2 Future Trends

Speaker research is emphasizing materials improvements for magnets and other parts of the speaker. Mitsubishi is developing a very lightweight, high permeability magnet material that they claim revolutionizes speaker design and reduces weight of the speaker magnet. Work is also proceeding on ferroresonant liquid materials for voice coil suspension. Both techniques should result in lower distortion and greater dynamic range. Work in speaker enclosures is trending toward improving the very thin profile enclosure.

Table 2.3-1

Speaker Specifications

Frequency Response	25-16000 Hz
Program Power Level	40 watts
Woofer Magnet Weight	4 lbs.
Tweeter Magnet Weight	6.8 oz.
SPL (1 kHz at 1 watt input, 4 ft. from speaker)	94.5 dB
Dispersion Angle	120°
Input Impedance	16 ohms
Crossover Frequency	1600 Hz
Nominal Diameter	15 inches

Table 2.3-2

Speakers and Enclosures

Manufacturer	Model	Frequency Response (Hz) (3 dB points)	Recommended Input Power (RMS) (watts)	Sound Pressure Level	Impedance (ohms)	Dimensions	Crossover Frequencies (KHz)	Net Weight (lbs.)	Price
Fisher	ST640 (Enclosure)	15 dB 42-20000	30-90	92 dB @ 1 meter w/1 w.input	8	10",6.5",4"	0.7/7	37	$249
Fisher	ST660 (Enclosure)	±5 dB 39-22000	40-125	94 dB @ 1 meter w/1 watt in.	8	10",6.5",4"	0.7/7	45	$299
Fisher	XP320 (Enclosure)	±10 dB 70-15000	8.5-25	-	8	8",2"	5	12	$80
Fisher	XP330 (Enclosure)	±10 dB 60-18000	17-50	-	8	12",5",3"	1.5/5	27	$160
Fisher	XP85A	45-20000	20-60	-	8	12",5",3"	1.5/5	36	
Soundesign	0695 (Enclosure)	-	10	-	8	8"	-	-	N/A
"	0730 (Enclosure)	-	35	-	8	12",5",3"	-		N/A
Tandy Corp. Radio Shack	40-1214	-	9	-	8	5"x7"	-	1	$8
"	PA-8 Outdoor Power-horn	340-9000	15	-	8	8"	-	5	$30
RCA	LC-1	25-16000	40 (Program)	94.5 dB w/1 watt input	15	15"	1.6	5	$199

Table 2.3-2 (continued)

Manufacturer	Model	Frequency Response (Hz) (3 dB points)	Recommended Input Power (RMS) (watts)	Sound Pressure Level	Impedance (ohms)	Dimensions	Crossover Frequencies (KHz)	Net Weight (lbs.)	Price
RCA	SL-8	50-18000	10 (Program)	92 dB @ 4 ft. w/1 watt input 1 KHz	8	8"	-	2.3/4	$11
RCA	SL-890	50-18000	15 (Program)	96 dB @ 4 ft. w/1 watt input 1 KHz	8	8"	-	2.1/2	$7
RCA	SL-12	50-16000	10 (Program)	95 dB @ 4 ft. w/i watt input 1 KHz	8	12"	-	4	$19
RCA	LC-9 (Enclosure)	50-16000	35 50 Program	-	16	15",1.3/4"	500 Hz	175	$600

Table 2.3-3

Speaker Manufacturers

Fisher Corporation
21314 Larsen St.
Chatsworth, CA 91311
213-998-7322

RCA Broadcast Products
Front and Cooper Sts.
Camden, NJ 08102
609-963-8000

Harris Corporation
Broadcast Products Division
P.O. Box 290
Quincy, Ill. 62301
217-222-8200

Altec Sound Products Division
1515 S. Manchester Dr.
Anaheim, CA 92803
714-774-2900

Lear Siegler, Inc.
Bogen Division
Rt.4 and Forest Ave.
Paramus, NJ 07652
201-343-5700

Klipsch and Assoc. Inc.
Dept. G
P.O. Box 688
Hope, AR 71801
501-777-6751

Electro Voice, Inc.
Subsidiary of Gulton Ind.
600 Cecil St.
Buchanan, MI. 49107
616-695-6831

Jensen Sound Labs Division, Pemco
4136 United Parkway
Schiller Park, Ill. 60176
312-671-5680

James B. Lansing Sound Inc.
8500 Balboa Blvd.
Northridge, CA. 91329
213-893-841

Soundesign Corp.
34 Exchange Pl.
Jersey City, N.J. 07302
201-434-1050

Radio Shack
Division of Tandy Corp.
P.O. Box 2625
Fort Worth, TX 76101
817-390-3011

Sanyo Electric Inc.
51 Joseph Street
Moonachie, NJ 07074
201-641-2333

2.4 AUDIO AMPLIFIERS.

2.4.1 General Description and Specifications.

Audio amplifiers are used as program output amplifiers to speakers, as low impedance preamplifiers for microphone inputs, as program monitors, and as distribution amplifiers. Audio amplifiers are produced for stereo amplification in the consumer market and for use in the audio broadcasting field. Since these amplifiers are often located between receivers and speakers, and between microphones and transmitters, their important characteristics include frequency response plus input and output impedances. Output power level is generally used to classify these amplifiers. In matching amplifier and monitor amplifier applications, input impedances are usually 600 or 150 ohms, while output impedances are either 600 ohms or 4/8/16 ohms for speaker attachment. Broadcast quality amplifiers usually have a high impedance bridging input (20,000 ohms) as well. Distribution amplifiers convert one input line to several isolated outputs while matching both input and outputs.

Harmonic distortion and frequency response are the specifications for an audio amplifier which fairly well indicate how the actual audio output will sound. With stereo amplifiers other parameters such as gain and phase matching between stereo channels are important.

Program and monitor amplifiers are priced anywhere from $100 to $500, with the higher priced models having wider frequency response, higher power, and lower harmonic distortion. With additional features, such as limiting-clipping for FM stereo broadcast applications, audio amplifiers can range easily above $1000.

Curves are available in radio engineering handbooks for selecting power amplifier sizes as a function of room volume. Efficiency of the attached speakers must be considered.

Table 2.4-1 shows a respresentative set of specifications for an audio amplifier. Table 2.4-2 shows comparative specifications on several high-fidelity, stereo, and broadcast quality amplifiers. Table 2.4-3 lists amplifier manufacturers.

Table 2.4-1

Audio Amplifier Specifications

Source Impedance	600/150 ohms, balanced
Matching Input Impedance	600/150 ohms
Bridging Input Impedance	20000 ohms
Load Impedance	4/8/16/150/600 ohms
Matching Input Level	-15 dBm max.
Bridging Input Level	+13 dBm max.
Frequency Response (20-20000 Hz)	± 0.75 dB
Output Level	10 watts
Harmonic Distortion	0.5% rms, Max.
Gain, Matching	55 dB
Noise Level Referred to:	
Input (20-20000 Hz)	-126 dBm
Output (20-20000 Hz)	-44 dBm
Power Requirements	115/230 VAC, 50/60 Hz, 35 watts

Table 2.4-2

Amplifiers

Manufacturer	Model	Type	Frequency Response (Hz)	Gain (dB)	Output Power Level (watts)	Harmonic Distortion	Noise Level	Input Sensitivity	Impedence Input/Output	Price
RCA	SA-1000 TR	Multi-purpose	20-20000 $\pm$ 2 dB	75	100	2% max.	80 dB below rated output	-8 dBm for rated output	600 ohms bal. 14,8,16,50 ohms	$235
RCA	SA-115	General purpose	30-15000 $\pm$ 2 dB	-	10	1%	70 dB below 8 watts	-	15K ohms/ 8 ohms	$110
RCA	SA-1000	Bridging	20-20000 $\pm$ 2 dB	-	100	2%	93 dB below 100 w.	0.53 u. rms for 100 w.output	10K ohms/ 3.2,8,16 ohms	$165
RCA	SA-1004	Mixer Bridging Auxiliary Micro-phone	 20-20000 25-20000 25-20000	 58 88 113,123	100	2%	-93 dB -70 dB -53 dB below 100 w.	0.53 v 0.16 v 7,2.2 mv.	13.2,8,16 ohms	$300
RCA	BA-40	Distri-bution	20-20000 $\pm$ 1 dB	35 $\pm$ 0.5	+ 24 dBm	0.3%	-70 dBm max.	-10 dBm	10K ohms 600 ohms/ 600 ohms	$290
Kenwood	KA-8100	Stereo DC	20-20000	-	75 /channel	0.03% at rated output	115 dB S/N	0.8 mV.	50K ohms/ 8 ohms	$465
Kenwood	KA-810	Stereo DC	-	-	-	-	-	-	-	$600

Table 2.4-2 (cont'd)

Amplifiers

Manufacturer	Model	Type	Frequency Response	Gain (dB)	Output Power Level (watts)	Harmonic Distortion	Noise Level	Input Sensitivity	Impedence Input/Output	Price
Revox	B-750	Integrated Stereo	20-2000 KHz $\pm \frac{1}{2}$ dB	-	75 w./ channel	0.1% at rated output	Audio input >90 dB unweighted phone >70 dB	phono 1.5 mv. Aux. 200 mv.	phono 25K/50K/100K tuner or aux 100K output 4-16 ohms	$999.

Table 2.4-3

Audio Amplifier Suppliers

RCA Broadcast Systems Front & Cooper Streets Camden, JH 08102 609-963-8000	Lear-Siegler, Inc. Bogen Division Rte. 4 & Forest Avenue Pasamus, NJ 07652 201-343-5700
Harris Broadcast Products P.O. Box 290 Quincy, IL 62301 217-222-8200	Jerrold Electronics Corp. Dept. G Byberry Road & PA Turnpike P.O. Box 487 Hatboro, PA 19040 215-674-4800
Kenwood Corp. 75 Seaview Drive Secaucus, NJ 07094 201-863-5600	Shure Bros. Inc. 222 G Hartrey Avenue Evanston, IL 60204 312-866-2200
Heath Company Benton Harbor, MI 49022 616-983-3961	Studer-Revox America, Inc. 1819 Broadway Nashville, TN 37203 (615) 329-9576
Fisher Corporation 21314 Larson Street Chatsworth, CA 91311 213-998-7322	

2.4.2 Future Trends

A notable development in audio amplifiers is the appearance of the Class F or Class G amplifier. This amplifier operates in a switching mode in much the same manner as a switching power supply. Effectively, it is an analog-digital converter at the input and a D-A converter at the output with appropriate sampling and encoding. Wide frequency response, low distortion, and high efficiency are characteristics that are expected. Amplifiers of the present design types will continue to benefit from VLSI and miniaturization.

2.5 OTHER AUDIO EQUIPMENT.

2.5.1 General Description and Specifications

While other ancillary equipment such as power supplies, audio switches/mixers, fader consoles and the like will find application in an overall audio system such as a broadcast studio, only two additional pieces of equipment will be mentioned here. Audio patch panels may be used to interconnect other audio equipment, and various types of headsets possibly are used as terminus equipment.

Headsets are simply combination microphones and speakers, so they tend to combine the specifications of both types of equipment. Impedance levels, frequency response, and distortion levels are important parameters and are stated the same as for microphones or speakers. Headset prices range from $20 to $75 for a good stereo earphone-only headset in the consumer market to $100-$200 for headsets used in the broadcast industry. The higher priced units are microphone and earphone combinations with special noise-cancellation attachments for use in high ambient noise environments.

Patch panels and plugs are usually of the two-wire tip and ring (TR) or three-wire TRS (tip-ring-sleeve) type with two or three isolated contacts. Patch panels are available in many arrangements depending on which contacts are normal (i.e., connected when the plug is not inserted) and which contacts the plug activates. Plugs are available in single or double prong. Hole size is standardized but, obviously, must be compatible between plug and jack. Patch panels cost $2-$4 per jack.

Mixer consoles are used to connect many inputs to different outputs in a broadcast studio. They contain amplifiers, monitors, and fading controls for mixing different inputs at various power levels.

Table 2.5-1 lists some general specifications and prices of these equipments. Table 2.5-2 lists manufacturers.

Table 2.5-1

Other Audio Equipment

Equipment Type	Manufacturer	Model	Use	Price	Comments
Patch Panel	GTE - Lenkurt	5215B	Telephone or audio	$5/jack	
Patch Panel	RCA	BJ-20	Audio	$63	
Headphones	Koss	K-6 LC	Stereo	$20	
Headphones	Realistic-Radio Shack Tandy Corp.	Pro-11	Stereo	$50	10-22000 Hz Frequency Response
Headphones	" " "	Nova-30	Stereo	$22	30-18000 Hz
Headphones	" " "	LV-10	Stereo	$40	20-20000 Hz
Headphones	Sennheiser	HD-400	Stereo	$40	
Headset	RCA	M1410085	Stereo	$72	100-4300 Hz
Headset	RCA	M1410095	Commentator	$132	Noise cancelling microphone 100-5000 Hz
Headset	Sony	DR-10A	Intercom	-	Carbon mike 200 Hz - 5K Hz

Table 2.5-2

Other Audio Equipment Suppliers

Patch Panels

GTE Lenkurt
1105 Old County Road
San Carlos, CA 94070
415-595-3000

RCA Broadcast Systems
Front and Cooper Streets
Camden, NJ 08102
609-963-8000

Harris Corporation
Broadcast Products Division
P.O. Box 290
Quincy, Illinois 62301
217-222-8200

ADC Telecommunications
4900 W. 78th St.
Minneapolis, MI. 55435
612-835-6800

Earphones and Headsets

Koss Corporation
4129 N. Port Washington Ave.
Milwaukee, WI. 53212
414-964-5000

Radio Shack
Tandy Corporation
P.O. Box 2625
Ft. Worth, Texas
817-390-3011

RCA Broadcast Systems
Front and Cooper Streets
Camden, NJ 08102
609-963-8000

Sennheiser Electronic Corp. (NY)
10 W. 37th St.
New York, NY 10018
212-239-0190

Studio Audio Mixer/Fader Controls

RCA Broadcast Systems
Front and Cooper Streets
Camden, NJ 08102
609-963-8000

Harris Corporation
Broadcast Products Division
P.O. Box 290
Quincy, Illinois 62301
217-222-8200

McCurdy Radio Industries, Ltd.
108 Carnforth Rd.
Toronto, Ontario M4A 2L4
416-751-6262

Ward-Beck Systems, Ltd.
841 Progress Ave.
Scarborough, Ontario M1H 2X4
416-438-6550

Studer Revox America, Inc.
1819 Broadway
Nashville, TE 37203
615-329-9576

2.5.2 Future Trends

A significant trend in the development of audio mixers, control consoles and studio equipment generally is the increasing use of mini-computers and microprocessors for control. Complex mixer/control consoles using solid state crosspoint switchers will switch multiple program sources to multiple outputs, display the on-air and upcoming program events and schedule on CRT displays, log the program events, and even control remote receivers for network programs transmitted by satellite to affiliated stations, all under computer control. These techniques will be used for video programming as well as audio.

2.6 RECORDING EQUIPMENT.

2.6.1 General Description and Specifications

Audio recording equipments that might find public service terminus application are of three types:

Reel-to-Reel Recorders
Cassette Recorders
Cartridge Recorders

2.6.1.1 Reel-to-Reel Equipment

Reel-to-reel machines generally have been considered higher quality than the other types because of more stable tape travel and higher performance recording/playback heads. Reel-to-reel equipment is available for the consumer market in stereo recorders at prices ranging from a few hundred dollars to well over $1000. Akai America, Ltd. of Compton, California, is a representative manufacturer.

Even higher quality reel-to-reel equipment is available for the FM broadcasting market. Such machines are manufactured by Ampex Corporation, Redwood City, California; Studer Intl. AG, Wettingen, Switzerland (U.S. representative in Nashville, TN), Neve of Cambridge, England. These equipments range in price from $4000 to $9000 for 2-channel stereo units.

2.6.1.2 Cassette Recorders

The quality of cassette recorders for the consumer market is rapidly approaching that of reel-to-reel systems, especially when Dolby noise reduction is used. Table 2.6-1 compares specifications of typical reel-to-reel and cassette recorders on the consumer market. Optimum performance and specification compliance usually depend on using manufacturers' recommended tape.

Table 2.6-1

Consumer Tape Recorder Specification

Reel-to-Reel		Cassette
7.5 and 3.75 ips	Tape Feed	—
4 track, 2 channel stereo, 3 heads	Track System	2 track, 3 heads
0.12% WRMS @ 7.5 ips 0.15% WRMS @ 3.75 ips	Wow and Flutter	0.04% WRMS
30-23,000 Hz @ 7.5 ips 30-16,000 Hz @ 3.75 ips	Frequency Response (± 3 dB)	30-18,000 Hz
less than 1%	Distortion	1.4%
56 dB	Signal/Noise	64 dB (Dolby On)
100 kHz	Bias Frequency	95 kHz
40 W @ 120 VAC 60 Hz	Power Requirements	120 V, 60 Hz, 37 W
4-pole Induction Motor	Motor	1 DC-Servo, 1 DC-Governor
$800	Price	$500

2.6.1.3 Cartridge Recorders

Cartridge tape units are usually play-only machines that are used by broadcasting studios to play short, pre-recorded messages that are recorded on plastic encased cartridge tape rolls. Playing time varies from 30-40 seconds to 10-15 minutes. Cartridges are used for commercials, station ID or other short messages that are inserted into broadcast sequences. They can be mounted in carousels in large numbers and played on a pre-programmed basis. A single player-only cartridge machine for broadcast use, mono or stereo, costs in the neighborhood of $600-$1000. Specifications of such a machine are given below in Table 2.6-2.

Table 2.6-2
Cartridge Player Unit Specifications

Tape Velocity	7.5 ips
Frequency Response	
50-15,000 Hz	$\pm$ 2 dB
30-18,000 Hz	$\pm$ 4 dB
Distortion	0.5% THD
Signal/Noise Ratio	30 dB stereo, 55 dB mono
Wow and Flutter	0.2% RMS
Input/Output Impedance	150/600 balanced
Power Requirements	110/220 VAC, 50-60 Hz, 80 Watts

2.6.1.4 Tape Recorder Specifications

A number of comments are pertinent on the specifications listed in Table 2.6-3. First, each manufacturer tends to vary the measurement conditions somewhat, although many measurement conditions are set by standards, such as NAB (National Association of Broadcasters) or CCIR.* Therefore, we advise caution in comparing specifications too closely without examining the data sheets for each equipment to note the detailed measurement conditions. Prices can vary quite a bit within a given manufacturer's equipment, depending on accessories and the particular arrangement and number of features. Therefore, the prices given for the professional studio models are selected as a basic price which can be more or less depending on the exact model. No intent is made to compare prices for exactly equivalent performance. The reader should consult the specific manufacturer's catalog for precise price information.

The term "Wow and Flutter" is a measure of variation in capstan motor speed and tape speed and sideways slip and the effects on the accuracy of low and high frequency reproduction. Signal-to-noise ratio must be compared at a given tape speed and type, equalization, recording flux level and weighting. Therefore, accurate comparisons are not always possible. Most of the listed parameters were measured with NAB equalization, two track, and either unweighted or with "A" weighting. Variations of 3-5 dB can occur, so again the user should consult specific manufacturers' catalogs for complete information.

Distortion is usually given as third harmonic distortion (THD). This parameter also is measured with NAB or CCIR equalization. Some manufacturers use even-order harmonic distortion instead of third-order or total harmonic distortion.

A wide variety of features are available for professional tape recorders for the purposes of cuing, editing, tape control, level setting, and maintenance. Tape widths, number of tracks, and track separation are other variables. Most manufacturers recommend a specific tape, with the newer $Cr\ O_2$ tape being lower noise. Input and output levels and impedances also vary somewhat, but they usually cover all nominal interfaces with no problems. Table 2.6-4 lists manufacturers of audio tape recorders.

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* CCIR = International Radio Consultative Committee, a consultative committee in the International Telecommunications Union (ITU).

Table 2.6-3

Audio Tape Recorders

Manufact-urer	Model	Type	Tape Speed (ips)	Flutter & Wow to DIN 45507, peak weighted	Frequency Response ± 2 dB (Hz)	Tape Speed Accuracy	Distort-ion	S/N (dB)	Price
Studer	A80/RC	Professional reel/reel	7.5	0.06%	30-15000	±0.2%	<1%	61	$8780 (A80/RC-0.75 VU)
			15	0.04%	30-18000				
Studer	B67	Professional reel/reel	3.75	0.12%	40-12000	<0.1%	<1.5%	59	$5360 B67-0.75 VUK
			7.5	0.08%	30-15000		<1%	61	
			15	0.06%	30-18000		<1%	61	
Ampex	ATR-100	Professional reel/reel	3.75	±0.1%	30-10000	±0.03%	0.5%	64	Basic ATR-102 $6740
			7.5	±0.05%	30-15000		0.3%	71	
			15	±0.03%	20-20000		0.3%	69	
			30	±0.03%	35-28000		0.3%	72	
Ampex	ATR-700	Professional reel/reel	7.5	0.08% WRMS	100-15000	±0.3%	0.3%	60	Basic ATR-700-2 $1895
			15	0.08% " NAB wtg.	100-18000				
Fisher	CR1520	Consumer Stereo Cassette	-	0.04% WRMS	30-18000 ±3 dB	-	1.4%	64 w/Dolby	$500
Akai	4000DS	Consumer Stereo reel/reel	3.75	0.15% WRMS	30-16000	±2%	<1.0%	56	$400
			7.5	0.12% WRMS	30-23000 ±3 dB				
RCA	RT-21	Studio reel/reel	3.75	0.2% WRMS	40-75000	0.17%	1%	60	$2995 Stereo Dual Half-Track
			7.5	0.15% WRMS	50-15000				
			15	0.10% WRMS	50-15000				

Manufacturer	Model	Type	Tape Speed (ips)	Flutter & Wow to DIN 45507, peak weighted	Frequency Response ± 2 dB (Hz)	Tape Speed Accuracy	Distortion	S/N (dB)	Price
JVC	KD-85	Consumer Stereo Cassette	-	0.05% WRMS	30-16000 ±3 dB	-	0.9%	56	$500
Harris	90-2	Cartridge Record-Play	7.5	0.15% NAB wtg.	300-16000	0.1%	1.5%	50	$1305 mono $1560 stereo
RCA	RT-127	Cartridge Record-Play	7.5	0.2% unwtd.	50-15000	0.1%	3% max.	50	$1340 mono $1655 stereo
Revox	B-77	Reel-reel	3.75	<0.1%	30-16000	±0.2%	<1%	½tr. >65 ¼tr. >60	$1499
			7.5	<0.08%	30-20000 + 2 dB - 3 dB	±0.2%	<0.6%	½tr. >67 ¼tr. >63	

Table 2.6-4

Audio Tape Recorder Manufacturers

Ampex Corporation Audio-Video Systems Division 401 Broadway Redwood City, CA 94063 415-367-2011	US JVC Corp. 58-75 Queens Midtown Expressway Maspeth, NY 11378
Fisher Corporation 21314 Lassen St. Chatsworth, CA 91311 213-998-7322	RCA Broadcast Systems Front and Cooper Sts. Camden, NJ 08102 609-963-8000
Studer Revox America, Inc. 1819 Broadway Nashville, Tenn. 37203 615-329-9576	Harris Corporation Broadcast Products Division P.O. Box 290 Quincy, Ill. 62301 217-222-8200
Akai America, Ltd. 2139 E. Del Amo Blvd. Compton, CA 90220 213-537-3880	Soundesign Corp. 34 Exchange Place Jersey City, NJ 07302 201-434-1050
	TEAC Corp. Dept. G 7-3 Naka-cho 3 chome Musachino City Tokyo 180, JAPAN 0422-53-1111

2.6.2 Future Trends

Other than continued improvements in tape technology and materials for lower noise recording, the audio recording business may see some more revolutionary developments. The same principle that is used in the video disc is being used to produce what has become known as "digital audio" recording techniques. These new systems use ultra high density, pulse code modulation (PCM) to process audio signals, and they apparently boast extremely wide frequency and dynamic range. Familiar sampling, encoding, and error control techniques are used to produce the PCM signal which is then FM modulated and recorded on a disk using a laser beam. The laser beam literally burns small "pits" in a spiral track on the metallic surface of the disk. Conventional record reproducing techniques and facilities can then be used. Laser beams are also used for playback.

Apparently these developments are being led by Japanese manufacturers, and indications are that format problems may be avoided since they have tentatively agreed on a 14-bit linear coded system and a 44.0556 KHz sampling rate. Playing times as long as two and a half hours on one side have been demonstrated. Other performance specifications claimed include 20 Hz to 20 KHz 1 dB bandwidth, dynamic range greater than 85 dB, and harmonic distortion of less than 0.1 per cent.

2.7 RADIOTELEPHONE EQUIPMENT.

2.7.1 General Description and Specifications

This category of equipments enables people to make or receive phone calls via radio channels at an arbitrary location. Their major applications include air-to-ground communications, land mobile communications, and other communication purposes. Phone patches are also in this category because they connect radio channels to telephone lines. The purpose of this section is to provide a general description about basic operating characteristics and important specifications of these equipments.

2.7.1.1 Air-Ground Radiotelephone.

For air-to-ground communications, the user operates the equipments in the aircraft to communicate with the ground via specified ground stations. Some of them have a push-to-talk switch and others can be used exactly as a desk telephone in an office. Some of them have an ON/OFF control such that the user can assure absolute privacy from the interruption of undesired incoming calls. Most of them have a volume control to adjust the volume to an appropriate level. They usually need to be installed in aircraft; therefore, size and weight become important parameters. In general, the range of distance on the ground in which the radiotelephone works increases with the altitude of the aircraft. Therefore, ground station location is important to the user. When a user in the aircraft wants to make a call, he must be within range of an appropriate ground station to connect his call to the desired destination. Since the radio link operates at VHF/UHF, useable range is essentially line-of-sight. There were about 50 air-ground radiotelephone ground stations in the U.S. as of December 1, 1977.

2.7.1.2 Land Mobile Radio

For land mobile communications, the user operates the equipments in his automobile to talk to any other telephone. Some equipments have a push-to-talk switch and others can be used exactly as a desk telephone in an office. Most have lamps indicating that either the circuit is busy or available. Designs use different methods to notify the user that a call was received when the user was away and/or when the equipment was busy. The geographical area of the channel frequency coverage is, in general, much smaller than the air-to-ground communications, and an area selection switch is therefore sometimes needed on the equipment.

Mobile radio networks include base station transmitter/ receivers and repeaters. These equipments operate at about 50-100 watts for base stations and as high as 375 watts for repeaters. Frequency ranges are 25-50 MHz, 136-174 MHz, and 450-512 MHz.

2.7.1.3 Phone Patch

Phone patches are usually used to connect amateur or other channels to telephone lines. Tape recorders and some other additional capability can be added to the equipments. Some special amplifiers can be used to adjust weak signals to the desired level. The most important specifications are the values of input and output <u>impedance</u> for matching into the telephone lines and radio equipment. <u>Weight</u> and <u>dimensions</u> are also relevant. The specifications of a typical example are listed in Table 2.7-1.

2.7.1.4 Specifications: Air-to-Ground and Land Mobile Communications

Some of the critical specifications are discussed in the following paragraph. The <u>operating frequency range</u> is the first parameter because different bands are allocated and occupied by different services and have different propagation characteristics. For example, the 144-148 MHz band is the so-called 2-m band usually occupied by amateur radios. <u>Number of channels available</u> to the equipment is even more critical to

Table 2.7-1
Specifications of a Typical Phone Patch Equipment Model

Company:	Barker and Williamson, Inc.		
Model:	3002W, 3001W		
Impedances:	Input from	Line	600 ohms
		Receiver	4 ohms
		Microphone	50,000 ohms
		Tape Recorder	4 ohms
	Output from	Transmitter	50,000 ohms
		Receiver Speaker	4 ohms
		Tape Recorder	0.5 Megohms
Weight:	3.5 pounds		
Size:	6.5 x 7.5 x 3.0 inches		
Price:	3001W	$85	
	3002W	$125	

the users because this actually specifies the grade of service of the equipments to the user. For example, some mobile radio has only six available channels; therefore if in a particular area the density of users is very high, blockage occurs frequently. In such a case, suppose the average waiting time for a call to find an available channel is 15 minutes, but a particular user usually drives his car no more than 30 minutes each time. The grade of service of this equipment to the particular user must be very poor. Type of modulation determines the channel bandwidth and noise figure, but usually this is more important to the designers than to the users. Because the equipments are supposed to be placed in an aircraft, car, or carried by the user, the weight and dimensions of the equipment should also be considered by the user. The operating temperature range of the system depends upon the quality of the solid state components used in the equipment design, and determines the maintenance requirements of the equipments. The cost is in fact a function of all the above different parameters with different weighting factors. The typical values of the specifications of some land mobile model equipments made by a few representative vendors are listed in Table 2.7-2. Addresses and the telephone numbers of these vendors are listed in Table 2.7-3.

Table 2.7-2
Typical Values of the Specifications of
Land Mobile Radiotelephones Made by Representative Vendors

<u>Land Mobile Radiotelephone</u>

Frequency Range	144-148 MHz
Number of Channels	6 to 12
Modulation	FM
Weight	6 to 15 pounds
Dimensions	approx. 3 x 9 x 16 inches
Temperature Range	-30°C to +60°C
Price Range	$200 to $500

Table 2.7-3
Addresses and Phone Numbers of Typical Vendors
of Land Mobile Radiotelephones and Phonepatch.

Company	Address	Telephone
Harris Corp.	55 G Public Sq., Cleveland OH 44113	216/861-7900
	1680 G University Ave., Rochester NY 14610	716/244-5830
Hughes Aircraft	5250 W. Century Blvd. (P.O.Box 90515) Los Angeles, CA 90009	213/391-0711
Rydax, Inc.	76 Belvedere St., (P.O. Box 2368) San Rafael, CA 94901	415/457-4200
Henry Radio	11240 W. Olympic Blvd. Los Angeles, CA 90064	213/477-6701
Spectrum Communications	Box 140, Worcester, PA 19490	215/631-1710
Genave	4141 Kingman Drive Indianapolis, IN 46226	317/546-1111
King Radio (air-ground)	400 N. Rogers Rd., Olathe, KS 66061	913/782-0400
Wulfsberg Electronics (air-ground)	11300 West 89th St. Overland Park, KS 66214	913/492-3000
Land Mobile Comm. Div. M-A	1362 Borregar Avenue Sunnyvale, CA 94086	408/734-4220
Communication Assoc., Inc.	200 McKay Rd. Huntingdon Sta., NY 11746	516/271-0800
Barker and Williamson, Inc. (Phonepatch)	Canal St. Bristol, PA 19007	215/778-5581
Glenayre Electronics	8 - 12 St. Blaine, WA 98230	604/980-6041

2.7.2 Future Trends

The trend of developments in radiotelephone technology has more to do with overall communications industry events and the next generation of satellite systems than with the radiotelephone itself. Economic and technical studies indicate that the next generation of earth satellite will contain higher power transmitters and will make increasing use of high gain, shaped beam antennas. An adjunct to this development may well be the use of very small, very low power earth terminals for personal or business communications. Some papers and articles have discussed the use of "wrist radio" transceivers that will access the satellite and that will use the satellite link for entry into the world-wide telephone network.

Whether such a small size radiotelephone is practical or not, the trend is toward quite small earth terminals which are portable, low power, and which depend on very high power, very sophisticated switching in the satellite. In many cases, these terminals will be a radiotelephone, be it land or air mobile, or phonepatch, since they will be able to access the world-wide telephone network thru the satellite.

2.8 SUBSCRIBER LOOP RADIO.

A type of radiotelephone equipment which is sometimes used in remote areas in place of normal wire telephone is subscriber loop radio. In this system, the telephone network is used for the long range link while VHF radio between a base station and up to eight subscribers completes the link to the end user. The base station is located at a telephone exchange center. Each subscriber has a radio receiver-transmitter on his premises, and each uses a normal telephone set as the final terminus equipment. Specifications for an example system are given in Table 2.8-1.

The subscriber radio system is composed of three major subsystems: the control terminal, the base station radio complement, and the subscriber premise equipment. The following paragraphs describe, in summary form, this equipment and its function.

2.8.1 The Control Terminal

The control terminal is composed of line termination equipment, channel link equipment, and power supply. The line termination equipment, as the name implies, provides the interface for each subscriber line on a card per subscriber basis. The channel link cards provide the interface to each of the base radios provided on a link module per radio basis. The power supply will operate on standard central office battery plant from 24 volts to 60 volts with a positive ground.

2.8.2 Base Station Radio Equipment

The base radio equipment may be located at the central office or remotely by extending the channel circuits with four-wire voice frequency channels. The base radio is an FM full duplex transmitter/receiver pair which provides a four-wire circuit between the subscriber premise equipment and the control terminal. The four-wire circuits are provided by separate crystal-controlled oscillators in the transmitter and receiver, each providing one simplex circuit. The supervisory and signal functions are provided by logic boards which work in conjunction

Table 2.8-1
Rural Radiotelephone General Specifications

Frequency Range	146-174 MHz
RF Power Output	10 W base 1.5/10W subscriber
Channel Spacing	25/30 kHz
Duty Cycle	100% continuous
Operation	Full duplex
Modulation	Frequency
Receive/Transmit Freq. Spacing	4.5 to 7 MHz
FM System Deviation	± 5 kHz
System Audio Response	300-3400 Hz/CCITT Rec.
System Audio Distortion	less than 5%
Number of RF Channels	2 to 8
Signaling	Inband, decimal digital
Number of Subscribers	1 up to limitations of traffic handling requirements

with the control terminal logic. There is a power supply with this radio equipment which operates from a 117/220 volt source.

2.8.3 Subscriber Premise Equipment

The subscriber equipment consists of a subscriber radio unit, a voice frequency hybrid, and a standard telephone set. The radio unit is identical to the base radio unit except that the transmitter is locked to the receiver frequency with a prescribed offset. The receiver contains up to eight crystal oscillators set to the base transmitter frequencies. Receiver logic circuitry steps the receiver through the eight possible channels. The transmitter remains in step with the receiver and the offset frequency delta matches the base transmitter receiver offset. The subscriber radio equipment contains a power supply which operates from a 60 Hz, 117/220 volt source.

2.8.4 Miscellaneous Equipment

In addition to the equipment above there are antennas, isolators, cables, and harnesses which interconnect card cages, racks, panels and units, which provide radiation gain and frequency separation.

Control terminal equipment for a subscriber loop radio system for service to as many as 50 subscribers costs around $30,000, and base radio equipment costs about $24,000. Each subscriber premise set costs about $2500-$3000 in quantities of 50. Suppliers are listed in Table 2.8-2.

2.8.5 Future Trends

Subscriber loop radio is not a rapidly growing industry as such. However, increased quality and reliability of rural communications is of great interest. Advances in telephone technology, fiber optics, digital radio, and particularly in the use of high powered satellites with small, low-cost earth terminals will all contribute to the greater realization of reliable, low-cost rural communications.

Table 2.8-2

List of Miscellaneous Equipment Suppliers

Motorola Communications & Electronics Inc.
Dept. G
1301 E. Algonquin Road
Schaumburg, IL 60196
312/397-1000

Stromberg-Carlson Corp.
Subsidiary of General Dynamics Corp.
100 Carlson Road
Rochester, NY 14603
716/482-2200

2.9 SHORTWAVE RADIO.

One other type of radio that is of interest to the public service user operates in the so-called short-wave band just above the AM broadcast band. These bands are not heavily used in the U.S. and therefore most U.S. manufacturers do not supply them. U.S. manufacturers do supply so-called 5-band communications receivers which include the 150-400 kHz longwave, 550-1650 kHz AM, 1.5-4.5 MHz and 4.5-13 MHz shortwave, and 13-30 MHz Ham/CB bands. Other 5-band portable receivers can be tuned to the standard AM/FM bands plus the VHF Lo (30-50 MHz), VHF Hi (144-174MHz) and UHF (450-512 MHz) bands. Radio Shack is a major supplier of these types of receivers in the U.S. Price range from $50 for the portable VHF/UHF types to $160 for the AM/shortwave (up to 30 MHz) type. Specifications are generally not published, other than frequencies, and prime power requirements which are either 12 VDC or 120 VAC at about 0.5 ampere.

Foreign manufacturers such as Philips make a series of portable radios which receive AM plus 3.2-22 MHz in four bands. These radios operate at 230 VAC, 50 Hz or 6 VDC and consume about 10 watts. Prices are under $100 for small quantities. Suppliers are given in Table 2.9-1.

A major drawback of the shortwave band (3.2-22 MHz) is unreliable propagation because of weather and ionospheric conditions.

2.9.1 Future Trends

In a previous section of this compendium, it was noted that the high-powered satellite may bring about significant changes in the use of radiotelephones. By the same token, availability of very small, low-cost earth terminals may prove to be a more reliable and less costly means of providing radio broadcasting or communications now performed by shortwave radio. The major advantage of such a transition will be the greater reliability of reception at satellite frequency bands over the shortwave bands.

Table 2.9-1

Shortwave Radio Suppliers

Radio Shack Tandy Corp. P.O. Box 2625 Fort Worth, TX 76101 817/390-3011	Phillips Industries, USA Magnavox Co. 1700 Magnavox Way Fort Wayne, IN 46805 219/432-8516
Motorola Communications & Electronics 1301 E. Algonquin Road Schaumburg, IL 60196 312/397-1000	NEC America, Inc. 532 Broadhollow Road Melville, NY 11749 516/752-9700
Panasonic Company Division of Matsushita Corp. of America One Panasonic Way Secaucus, NJ 07094 201/348-7000	Nippon Electric Co., Ltd. Consumer Electronics International Division 33-1 Shiba Gochome Minato-Ku, Tokyo JAPAN

2.10 FACSIMILE.

2.10.1 General Description and Specifications

Facsimile is a form of electronic mail. Its application is to send and receive copies of almost anything that can be put on paper, such as words, drawings, charts, etc. Facsimile has the advantage of sending documents, contracts, sales orders, etc. immediately as the need arises, avoiding the delays inherent in messenger and mail services. The disadvantages of facsimile are the transmission costs, but these will go down as newer and faster machines become available, and through use of satellite transmission.

Facsimile machines can generally be classified by their speed of transmission, resolution, compatibility with other machines, transmission mode (digital vs. analog), and automatic vs. manual mode of operation. The cost of a single facsimile machine runs from $1200 (Qwip 1200) to $54,700 (Dest Data's DSD 500). The Qwip 1200 has either a 6-minute per page scan speed with a resolution of 96 lines to the inch both vertically and horizontally, or a 4-minute per page scan speed with a resolution of 64 lines to the inch vertically and 96 lines to the inch horizontally. On the other end of the spectrum, Dest Data's DSD 500 has a scan time of approximately 50 seconds with a resolution of 500 lines to the inch. Because of the high transfer speed, the Dest Data unit requires wideband transmission facilities. In between these two models various manufacturers have models with scan speeds ranging from a slow of 6 minutes per page to 1 minute per page.

The scan speed of the machine is important to a user depending on the volume of data which is transmitted and received each day and channel usage charges per minute. It may be worthwhile to invest in a more costly machine if the expense is made up by lower line usage charges. High resolution machines are useful when transmitting fine print, graphics or photographs.

Another area of concern to the user is the compatibility of the machines which must communicate with each other. Many manufacturers make machines which can only communicate with a similar machine. CCITT standards have been developed for medium and low speed machines, and systems for protocol are being established to allow greater communication between facsimile units.

Automation in facsimile machines is increasing as units are being made with automatic feed and automatic answer capabilities which reduce the cost of labor and supervision. Also, transmission can be saved for non-peak telephone rates and sent automatically. The cost for the automatic capability is generally higher.

Ease of operation may also be important to some users. The Qwip 1200, which is one of the most economical units available, requires relatively greater effort and time in feeding and aligning the paper before transmission. Units like the 3M 2346 are more expensive but are easy to operate with automatic document loading.

The latest technology advancement is a machine equipped with an optical character reader (OCR) which recognizes characters and encodes them in standard ASCII. These machines are only useful for transferring typed material and cannot be used for graphics or photographs. Typed material can be sent at high speeds and resolution using the OCR. Some present-day applications of OCR are to read draft typewritten copies into a word processor unit or as a replacement for telex or data communication terminals. Future development will bring facsimile and OCR together into one unit.

A list of general specifications and costs are given for some representative facsimile units in Table 2.10-1. A list of vendors presently manufacturing facsimile units is presented in Table 2.10-2.

Table 2.10-1

Representative Facsimile Units

Manufacturers	Model	Compatibility	Speed/Page	Resolution	Purchase Costs/Unit	Lease Costs: $/Month	Maintenance Policy
Dest Data Corp.	DSD 120	Serial digital bit stream. Option available to interface to specific computers and meet RS232EIA interface standards.	2.7-1.35 sec	120 points/inch	$18,400 each 1 to 9 units $6,900 each, 10,000 units or above	Dest Data leases its equipment at a monthly rate of 4% of purchase. 90% of lease applies toward purchase for first 3 months; 60% of lease applies toward purchase after 12 months.	Dest Data scanners have a single moving part; manufacturer claims this adds reliability and accuracy.
	DSD 240		10.8-3.6 sec	240 points/inch	$24,100 each, 1 to 9 units $9,050 each, 10,000 units or above		
	DSD 120/240			Combines by operator select resolution of either 120 or 240 points/inch	$28,400 each, 1 to 9 units $10,650 each, 10,000 units or above		
	DSD 500		50 secs	500 points/inch	$54,700 each, 1 to 9 units $21,900 each, 10,000 units or above		
	OCR/word	Standard interface for paper tape punch & EIARS232C devices	200 characters/sec 6(8½ x 11) pages/min average	6 lines/inch (single spaced) 4 lines/inch (space & half) 10 per inch character pitch	$20,000 basic unit with 1 of 3 fonts; with various options cost can run up to $55,000.		
Graphic Sciences	DEX 3400	Compatible w/ most 4,6 min units.	2,3,4, or 6 min	88 lines/inch in 3 or 6 min mode 62 lines/inch in 2 or 4 min mode			Maintain a worldwide sales/service organization.
	DEX 3000	Self-compatible only	3,6 min				
	DEX 4100 *	Compatible w/ most AM or FM units	2,3,4,4.5, 6,9,12 mins	62 lines/inch in 2 or 4 min mode 88 lines/inch in 3 or 6 min mode 124 lines/inch in 4.5 or 9 min mode 176 lines/inch in 6 or 12 min mode			
	DEX 5100 *	Compatible w/ 3 min units which comply w/CCITT fax standard	20 secs typical at 9600 bps	Express 65 x 204 LPI Normal 98 x 204 LPI Fine 196 x 204 LPI			

Table 2.10-1 (continued)

Manufacturers	Model	Compatibility	Speed/Page	Resolution	Purchase Costs/Unit	Lease Costs: $/Month	Maintenance Policy
Qwip Systems	Qwip 1200	Compatible w/ most other units.	4 or 6 min.	96 lines/inch horizontally & vertically @ 6 min.speed 64 lines/inch vertically @ 4 min.	$1,200 each, for 1-50 units $1,130 each, 100 or more units	$52/month, 1-9 units, $42/month, for 100 to 200 units, on a 12-month lease.	Service by replacement policy. Defective units are replaced with another.
	Qwip 2	Compatible w/ units meeting CCITT Group II standards	2 or 3 min	96 lines/inch horizontally & vertically @ 3 min speed. 86 lines/inch horizontally & 78 lines/inch vertically @ 2 min speed.	$1,900 each, for 1-50 units $1,800 each, 100 or more units	$65/month, 1-9 units; $62.50/month, for 100 to 250 units, on a 12-month lease.	
Teleautograph Corp.	Copyphone III		1.2 min or 3 min	83.3 lines/inch @ 3 min speed; 100 lines/inch @ 1.2 min speed.	$3,000 for transmitter or receiver	$95/month for 1.2 min speed transmitter or receiver; $85/month for 3 min transmitter or receiver	$420/year for maintenance, 1.2 min unit. $360/year maintenance, 3 min unit.
Xerox	200 *	All models are compatible with other Xerox telecopiers.	2,3,4, or 6 min	77 vertical, 80 horizontal lines/in @ 2 min speed;	$8,900, 1-3 units $8,300, 10 or more	$275/month, with 60% applying to purchase.	Maintains a world-wide sales/service organization.
	410		4 or 6 min	96 vert., 96 horizontal lines/inch @ 3 min speed;	$2,995, 1-10 units $2,695, 20 or more	$104/mo, 1-10 units; $94/mo, more than 75.	
	400		4 or 6 min	64 vert., 96 horizontal lines/inch @ 4 min speed; 96 vert., 96 horizontal lines/inch @ 6 min speed.	$1,800, 1-25 units $1,480, 100 or more units.	$64/mo., 1-10 units; $52/mo., more than 200 units.	
3M Telecom Products Division	2346	Compatible w/ most other units.	2,3,4,6 mins	96 lines/inch horizontal; 96 lines/in. vertical in 3 or 6 min mode. 96 lines/in. horizontal; 64 lines/in. vertical, 2 and 4 min mode.	$2380/unit Quantity discounts are available.	$76/month on 1-year lease	Maintain a world-wide sales/service organization. Service agreements can be obtained at additional cost/yr.
	Express 9600 *	Compatible w/ itself only. Compatibility with slower units planned as a future addition.	35 sec	96 lines/inch horizontal and 123 lines/in. vertical	$14,500/unit	$295/month on 1-year lease	

Table 2.10-1 (continued)

Manufacturers	Model	Compatibility	Speed/Page	Resolution	Purchase Costs/Unit	Lease Costs: $/Month	Maintenance Policy
Panafax	MV 1200	Compatible with most 4,6 minute analog machines. Conforms to CCITT recommended Group I (6 min.) and Group II (3 min.) standards.	2, 3, 4, or 6 minutes	80 by 78 lines/in. in the 2 min. mode; 96 by 64 lines/in. in the 4 min. mode; 96 by 96 lines/in. in the 3 and 6 min. modes.	$4,500 with an additional $750 for an automatic document feeder, and $850 for an automatic dialer. (Government purchase price: $4,230)	Monthly rental charge without options: $69.50. Annual maintenance contract for purchased units: $350.	Maintain a nationwide maintenance organization.
	UF-20						
	UF-320						

*Can be operated automatically without operator attendance.

Table 2.10-2

List of Facsimile Manufacturers

Alden Electronic & Recording Equipment Co. Alden Research Center Westborough, MA 01851	(617) 366-8551
AM International 1900 Avenue of the Stars Los Angeles, CA 90067	(213) 556-9500
Dest Data Corp. 1285 Forgewood Ave. Sunnyvale, CA 94086	(408) 734-1234
Faxon Communications Corp. 150 North Hill Ave. Pasadena, CA 91106	(213) 796-0251
Graphic Sciences, Inc. Commerce Park Danbury, CT 06810	(203) 792-6000
Harris Corp. Electronic Systems Div. P.O.Box 37 Melbourne, FL 32901	(305) 727-6201
Infolink Corp. 1925 Holste Rd. Northbrook, IL 60062	(312) 291-2900
ITT Creed Hollingbury Brighton East Sussex BN1 8AL,UK	0273 507111
Litton Systems, Inc. Datalog Div. 1770 Walt Whitman Rd. Melville, NY 11746	(516) 694-8300
3M Telecom Products Div. 3M Center St. Paul, MN 55101	(612) 733-6753
Muirhead, Inc. 1101 Bristol Road Mountainside, NJ 07092	(201) 233-6010

Table 2.10-2 (cont'd)

List of Facsimile Manufacturers

Muirhead Ltd. Croyden Rd. Beckenham, Kent BR3 4BE	01-650 4888
Parafax Corporation 185 Froehlich Farm Boulevard Woodbury, NY 11797	(516) 364-1400
Plessey Communication Systems Ltd. Beeston, Nottingham, UK NG9 1LA	(0602) 254822
Qwip Systems 1270 Ave. of the Americas New York, NY 10020	(212) 398-5000
Rapicom, Inc. Seven Kingsbridge Rd. Fairfield, NJ 07006	(201) 575-6010
Secre Usine Et Services Commerciaux 214-216 Fbg St. Martin 75010 Paris, France	203.00.11
Siemens AG Bereich Fernschreib-und Datenverkehr HofmannstraBe 51, D-8000 Munchen 70	(089) 722-26193
Telautograph Corp. 8700 Bellanca Ave. Los Angeles, CA 90045	(213) 641-3690
Telemechanics, Inc. 269 Maple Place Mineola, NY 11501	(516) 741-8544
Xerox 1341 W. Mockingbird Land Dallas, TX 75247	(214) 630-2611

2.10.2 Future Trends

In recent years we have seen technical improvements in facsimile units such as signal compression techniques for increased transmission speeds, improved scanning methods using photodiode array and charged coupled devices and development of store and forward systems in facsimile transmissions. In the future we are likely to see further automation, higher speeds without loss of quality and greater compatibility between different models. Facsimile equipment is likely to extend its communication capability to other kinds of office equipment including communicating typewriters and office copies. Facsimile users still pay more for telephone line charges than for the facsimile equipment itself. So lower line costs resulting from new technologies such as satellite communications and fiber optics will increase the use of facsimile in cost effective electronic mail systems. As office equipment and secretarial functions become more automated facsimile may become a generic term which refers to a variety of equipment and capabilities.

But facsimile could also face increasing competition from computer communication terminals once systems like AT&T's proposed Advanced Communication System (ACS) provide a universal protocol capability allowing a diversity of terminals to talk to each other. In the interest of efficiency desk side hybrid transmission equipment may supersede the stand alone facsimile unit. What will most likely happen is a classification of users with the high end user integrating facsimile into elaborate electronic mail systems and the low end user utilizing more simple forms of stand alone units.

3. DATA/GRAPHICS TERMINALS

The subject of this section of the Terminus Study is Data/Graphics Terminals. The main area of interest is in the terminal itself, which includes such devices as cathode-ray tube (CRT) terminals, keyboard terminals and printers, and graphics terminals. These devices are the input/output equipments where the man/machine interface occurs in moving data over a communications link. There are, however, other terminus devices and systems that complete this link, and these equipments also are treated in this section. For example, a CRT terminal or keyboard/printer usually is part of a larger data communications system in that the terminal may be "talking" to a computer or data processing system at the other end of the communications link. For this reason, this section includes some descriptive material on data communications networks and the computers and processors that are part of such networks.

The detailed discussion of digital computers is outside the scope of this study, so we mention them only briefly. We mainly discuss the smaller minicomputer and mid-range computers that are used as message concentrators and front end processors in large data communication networks. No discussion of computer applications today would be up-to-date without material on microprocessors, so these devices are included in the discussion.

Terminals have been traditionally used for converting human inputted messages into bit groupings for transmission to a computer or other terminals. Over the years applications for terminals have broadened considerably. Advances in solid state technology and new printing mechanisms have resulted in faster, more versatile and operator-efficient terminals. The use of microprocessor technology has permitted the expansion of off-line data preparation, text editing and message batching. Thus data can be prepared and edited and then sent over the transmission line at high speeds, saving line connect time and transmission costs. Features which have been introduced by various terminal manufacturers include:

- Two color printing
- Switch selectable communication speeds
- Built-in modems or telephone couplers
- Automatic error detection
- Extensive peripheral storage capability, including magnetic cassette and disc drives.
- Up to 180 characters per second printing speeds.
- Operator changeable character sets.
- Reverse printing.
- Graphics capability

In this section we have classified data terminals into the categories of teleprinter terminals, display terminals and Receive-Only printer terminals. Data modems, used as the data stream/transmission link interface are listed and discussed separately.

3.1 DATA COMMUNICATION NETWORKS

A rapidly growing phenomenon in modern communications technology in today's world is the use of computers tied together in a data communications network. These computers and various peripheral devices may be separated by only a few yards in the same building, or they may be located halfway around the world from each other. Entire books have been written about different aspects of these systems,* so coverage here must be cursory and general. The basic purposes of these data communications networks are the transfer of large blocks of data from one point to another, and the use of a large, host computer in a timesharing mode by terminals and peripheral devices at remote locations. The host computer in such applications is usually a large, mainframe, general purpose digital computer, such as the IBM 360/370 series. These computers generally are designed to perform batch processing of large amounts of data. Other than mentioning a few of the generic types of such computers, we will not be discussing these machines in this section. The link between these computers and their peripheral units can be telephone lines,

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*Martin, J. L. Computer Networks, for example.

microwave relay, and of course, satellite systems. At the other end of this communications link can be a staggering array of smaller computers, CRT and keyboard terminals, business machines, and complete data processing systems. Herein we discuss in some detail the specification and operation of these data processors, communications terminals, and input/output devices.

The host computer maintains control of this overall communications system in several ways. The host may poll the terminals in sequence to see if they have anything to transmit, or the various terminals may contend for the main computer's attention by means of dial-up telephone lines or thru a limited number of access ports. The host computer has a certain communications and operating protocol, and the remote terminals must either be compatible with this protocol, or else the terminals must be connected to another remote computer which puts the data into the proper format before transmitting it to the host computer.

Typical public service applications for such computer networks are the linking together of widely separated educational institutions, or communications between hospitals or medical facilities to exchange medical or educational records, educational material, or medical diagnostic data. Access to data banks such as Lockheed's information retrieval system is also typical.

When communications networks become so complex that dial-up lines or dedicated lines cannot handle the traffic, a technique called message switching or packet switching is used. In these systems large computers, often in a redundant configuration, use high-level software to support many simultaneous operations, such as polling, queuing, and broadcasting. The computer time-multiplexes various messages from origination point to destination according to message header instructions and priority assignments. Large amounts of disc storage are used in such systems for message queuing. Often a series of such computer switching points are arranged as nodes in a network, and messages are routed to their destinations by priority thru the switching nodes. This section discusses applications and presents information on computers that are used as front-end processors, message concentrators, and remote job entry systems in a data communications network. These computer types fall in the category of large to medium special purpose computers, minicomputers, and microprocessors. We will discuss each of these applications separately and give examples of computer types that might be used for each application.

3.1.1 Front-end Processors

Since it often happens that the various remote terminals in a computer communications system must be different because of the users' needs, a front end processing system is often used. Instead of modifying the host computer's software to accept many different kinds of messages, a front end processor is used to accept the different terminal line protocols or codes and to convert them to the host computer's format. The specific jobs performed by such systems are the real-time, interactive tasks, such as line polling and addressing, message routing, buffering and queuing, error checking and code converting. This type of operation leaves the host computer free to do its main job, namely, batch processing. In case of failure of the host computer, the front end processor can take over some of the essential services until the main computer is restored.

Examples of computers used for front end processing are Data General's ECLIPSE and NOVA systems, the new IBM System 38, and the Digital Equipment Corporation PDP-11/ series computers. These computers are packaged in several sizes and are capable of handling many input/output terminals. In the larger versions, they may include several hundred megabytes of disc storage (memory) for message queuing and system backup. The software for these computers controls communications and preformats messages to the host processor's format. They use a combination of high-level languages such as COBOL, FORTRAN or BASIC, and operating systems (overall supervisory and job control) to handle the different inputs and data formats on a timeshared basis. These computers are large enough to act as complete, self-contained computer systems, controlling a series of transaction terminals and memories, as well as communicating with the host computer.

3.1.2 Message Concentrators

A message concentrator stores and sends messages from low-speed remote terminals to a higher speed host processor. The messages are sent either in periodic high-speed bursts or are stored until the concentrator's line is polled. More efficient line use is the main characteristic of this store-and-forward technique. The message concentrator is much like the front end processor in that it relieves the host computers of jobs better done elsewhere, such as message validating, protocol and line speed checking, and error detecting and correcting. It also contains large amounts of disc storage capacity for storing messages until line capacity is available.

Again the Data General ECLIPSE series and DEC's PDP-11 series are prime examples of this computer type.

3.1.3 Remote Job Entry Systems

A remote job entry (RJE) system is a simple data entry terminal connected to a host system. It performs one function only and can be used for data entry or readout. Such systems, however, can be combined with minicomputers or microprocessors to provide local processing capability to the terminal functions. For instance, a RJE system may be used to talk to a host computer during the day and to run local computing jobs at night.

These systems consist of a minicomputer with its associated memories, central processor, and CRT terminals or printers. The host computer can print out messages on the printer or store them in the RJE system's memory. The terminal can talk directly to the host computer or store messages in memory for later transmission. Merchandising stores, airline reservation systems, and other types of local transaction systems use minicomputers or microprocessors.

An important characterisctic of RJE systems is called emulation. This means that the RJE can be programmed to operate in such a way that a different brand of host computer thinks it is talking to one of its own brand of simple terminal. Emulation systems are available in the software for RJE systems.

Data General's NOVA 3/D, DEC's PDP-11/02, 11/03 and 11/04 and the Hewlett-Packard 2100 A Series are examples of such computers. Various business machine companies make small computers of this type. An example is Sperry-Univac's BC/7 series. The rapidly growing list of available microprocessors also can be used for this purpose. Many of the terminals to be discussed in Section 4 have microprocessors incorporated into their design, thus making them "intelligent terminals".

3.1.4 Computer Types

A modern computer is a system consisting of a central processor or arithmetic logic unit, a control unit, memories, and various peripheral input/output devices connected by data paths or buses, as well as address and control buses. Because of the modular nature of the computer, its specifications are almost impossible to reduce to a simple list of operating characterictics. Computer sizes now run from the large, mainframe computers occupying an entire room to the newer microprocessors, now available as a complete computer on one or two printed circuit boards. Hardware characteristics of interest to the system designer are such matters as word size, both for data and addressing, memory size and type, bus arrangements, and cycle time (speed of processing one instruction). Compatability of these specifications among computers and among peripherals are at least as important as absolute values. The various protocols and operating systems used on computers also must be compatible or adaptable for data communications applications. Various techniques for addressing memory are available, and the more of these techniques that can be used on a computer, the more flexible it is. An example is direct memory addressing (DMA) which allows high-speed transfer of data directly between memory and an input/output device.

One of the most important aspects of computer selection is the software available. Vendors usually offer three kinds of software: operating, diagnostic, and program development. Operating software includes the various user application programs, loaders, operating systems, and subroutines. Diagnostic software is used to debug and troubleshoot the hardware and software. Program development software includes assemblers, editors, and compilers used to make the transition from high level languages to machine language and to edit the various programs. The software for a computer often can cost almost as much as the computer itself and should be carefully investigated during a purchase.

3.1.4.1 Large Computers

Large mainframe computers that might be used as the host computers discussed in this report are systems such as the IBM S/360/370, Data General Corporation's ECLIPSE M/600 or 1200, Control Data Corporations 7600 Series, Sperry-Univac's Series , and possibly Digital Equipment Corporation's PDP-11/70. DEC's new System 20 also falls in the large computer category for capability. These types and brands are mentioned for general information and background and are not the only systems on the market. These computers are available with mass storage consisting of multiple 96- or 190- Megabyte discs, magnetic tape units, as well as peripheral printers, card readers, displays, and various communications units. Their prices range well into the multiple hundred-thousand-dollar levels.

3.1.4.2 Mid-Range and Mini-computers

Almost every computer manufacturer now produces at least one model of a minicomputer. These systems are not as large as mainframe machines, but, when all peripherals are included, they can occupy several equipment cabinets. These computers might be used as front-end processors or message concentrators. These machines at the lower end of the range might also be used in remote job entry systems. Minicomputers are mostly sixteen bit machines and memory capacity can be anywhere from 8K to 64K or 128K in main memory with up to several hundred megabytes in auxiliary memory. Prices vary widely, depending on peripherals and memory capacity, but the range is from $25,000 to $85,000 for smaller models, and from $100,000 to $250,000 for the higher end equipment with multiple hundred megabyte memory capacity.

Representative minicomputer models are the IBM System/38, DEC 11/03 thru 11/70, Data General Nova 3/ and 4/ and Eclipse S/130 and S/230, Control Data Cyber 18-5, 18-20, and 18-30, Honeywell Level 6, and the Sperry-Univac BC-7 series.

3.1.4.3 Microprocessors

The trend toward distributed processing wherein computers at different locations are tied into a central computer over a communications link also has resulted in the use of microprocessors in such applications. Microprocessors are now available with fairly large quantities of memory and the capacity to handle a large number of peripheral devices. Again, because of the fact that memory can be expanded almost indefinitely it avails little to try to compare these processors and their specifications. Generally, their configuration includes a CPU, RAM, ROM,*interfaces for various peripheral devices, and usually some sort of communications adapter. Software is available in much the same way as for larger computers. The hardware for a complete microprocessor can be purchased, either separately or integrated on a circuit board, for well under $1000. Software costs run into several thousands of dollars if the user application program is included. The following microprocessors are prominent on the market today:

Company	Microprocessor Series
Motorola	M6800
Intel	8080
Fairchild	F8
Zilog	Z-80
Imsai	8080
National Semiconductor	PACE
Data General	MicroNOVA
Harris Semiconductor	6100
RCA Solid State Division	COSMAC 1802

* CPU = Central Processor Unit, RAM = Random Access Memory, ROM = Read-Only Memory.

Table 3.1-1

Computer and Processor Manufacturers

Large Computers and Minicomputers

Burroughs Corp. OEM Sales Dept. G 460 N. Sierra Madre Villa Pasadena, CA 91109	Telephone Number: (213) 351-6551
Data General Corp. Dept. G Rt. 9 15 Toke Rd. Westboro, MA 01581	(617) 366-8911
Hewlett-Packard Corp. Division 1501 G Page Mill Road Palo Alto, CA 94304	(415) 493-1501
Digital Equipment Corp. 129 G Parker Street PK3/M18 Maynard, MA 01754	(617) 897-5111
Honeywell Info. System Dept. G. 200 South Street Waltham, MA 02154	(617) 890-8400
Texas Instrument Inc. Dept. G P.O.Box 5012 Mail Station 84 Dallas, TX 75222	(214) 238-2011
NCR Corporation Dept. G 1700 S. Patterson Blvd. Dayton, Ohio 45479	(513) 449-2000
IBM Data Processing Div. 1133 G Westchester Ave. White Plain, N.Y. 10604	(914) 696-1900
CDC Dept. G P.O.Box 0 Minneapolis, MI 55440	(612) 853-7600

Sperry-Univac Corp.
Sperry Univac Div.
2722 G
Michelson Drive
Irvine, CA 92713 (714) 833-2400

Microprocessors

Intel Corp.
3065 Bowen Ave.
Santa Clara, CA 95051 (408) 246-7501

Motorola Semiconductor Products, Inc.
Box 20912
Phoenix, AZ 85036 (602) 244-6900

Fairchild Semiconductor
464 G Ellis St.
Mountain View, CA 94042 (415) 962-5011

National Semiconductor Corp.
2900 G Semiconductor Dv.
Santa Clara, CA 95051 (408) 737-5000

RCA Solid State Division
Dept. G.
Somerville, N.J. 08876 (201) 685-6000

Harris Semiconductor Group
Dept. G.
P.O.Box 883
Melbourne, FL 32901 (305) 724-7000

Signetics Corporation
U.S. Philips Corp.(Bin 27-GB)
811 E. Arques Ave.
Sunnyvale, CA 94086 (408) 739-7700

Zilog Inc.
10460 G Bubb Rd.
Cupertino, CA 95014 (408) 446-4666

Imsai Mfg. Corp.
14860 G Wicks Blvd.
San Leandro, CA 94577 (415) 483-2093

3.2 TELEPRINTER TERMINALS.

3.2.1 General Description and Specifications

Teleprinter terminals normally operate at speeds from 50 to 1800 bps, with many terminals offering a switch selectable speed capability. These devices come either in buffered or unbuffered configurations. They are available as Keyboard Send and Receive (KSR), AutomaticSend and Receive (ASR) or Receive Only (RO) devices. For unbuffered terminal devices the transmission speed is dictated by the printing speed of the terminal, or while sending information the transmission speed can be only as fast as the operator's typing speed. Buffered terminals with off-line editing and message preparation capabilities can be used for transmitting data at speeds independent of the printing or operator typing speeds. This capability can be important when considering transmission time charges.

In some applications portability of terminals is important. This enables highly mobile users like salesmen or doctors to access data bases from various different locations using the dial-up network. An item which must be considered in the selection of a terminal is its communication compatibility. It is desirable for a terminal to be flexible enough to operate over leased lines and dial-up lines in half-duplex or full-duplex operation and be capable of accommodating a number of character codes such as ASCII,EBCDICand other individual codes used by vendors.

Based on capabilities such as unbuffered or buffered, printing mechanism, printing speed,off-line editing, graphics capability and choice of character codes, teleprinter prices range from $800 to $5000. Table 3.2-1 gives the description and costs of some representative models while Table 3.2-2 gives a list of manufacturers for teleprinter terminals. Costs of terminals are continually changing and older models are being replaced by cheaper and better models. Thus before a terminal is selected prices should be cross-checked and manufacturers consulted on future product developments.

Table 3.2-1

Parameters For Teleprinter Terminals

Manufacturer	Description	Purchase Costs	Service/Lease Costs
Digital Equipment Company	Model LA36: KSR terminal which can operate at 30 cps or 300 baud. Print format is 132-column with 10 characters/inch horizontal spacing and 6 lines/inch vertical spacing. ASR capability can be obtained with an electronic send/receive option. Selective addressing option available.	In quantities of 100, purchase cost is $1295 terminal. Single terminal purchase cost is $2100. Send/receive option at $375. 4000 character buffer at $370. 16,000 character buffer at $750. Selective addressing option: $95/terminal	No lease option; $19/month service charge. $3/month extra service charge for ASR capability.
	LA35: R/O version of LA36.	$1900 list price. $1215 in quantities of 100.	
	EIA-RS-232-C Interface Option	$45 each.	
	Model LS-120: KSR terminal which can operate at speeds from 300 baud to 1200 baud with up to 180 cps print speed. ASR option has not yet been developed. Standard model comes with an EIA-RS-232-C	In quantities of 100, purchase cost is $2270. Single terminal purchase cost: $3990.	$34/month service charge.
	Model LA120: Speeds from 50 to 9600 baud. Print speeds from 180 to 200 cps. Will replace the LS-120.	$2550 list price.	$25/month service charge.
	Integral modem with Data Access arrangement.	$310 each.	

Manufacturer	Description	Purchase Costs	Service/Lease Costs
Teletype	Model 33: KSR or ASR Terminal which can operate at 10 cps or 110 baud. Line length is 72 characters at 10 characters per inch.	ASR:$1203 KSR: $844	$288 for 3 service calls/yr, unlimited repairs, for Zone 1 and 0-4 hours of usage.
	Modem with manual originate manual or automatic answer, included.	ASR: $1471	
	Data set coupler with motor control for automatic answer.	$295.00	
	Model 43: KSR or ASR terminal which can operate at 10 or 30 cps or 110 to 300 baud. Prints up to 72,80 or 132 char/line at 13 char/in. Comes with EIA-RS232C interface	KSR: $1235 Prices for the ASR version are still unknown. A tentative price estimate is $2600	$216 / year for 1 service call unlimited repairs. Can be leased for $58/month including maintenance.
	With built-in modem included.	KSR: $1587	
	Model 43 BSR: A buffered terminal which can operate at speeds up to 1800 bps. Printing rate is 30 cps. Basic buffer size is 4 K characters expandable to 20 K	4 K BSR:$2700 16 K BSR: $2800	Can be leased for $113/month including maintenance.

Manufacturer	Description	Purchase Costs	Service/Lease Costs
		A 15% discount is available to non-profit educational institutions public and private and to state, country and municipal governments and their Canadian equivalent. A 30% discount is available to OEM's and to U.S. and Canadian Federal Governments and their prime contractor.	
Texas Instruments	Model 743: KSR terminal which operates at 10 or 30 cps or up to 300 baud. Line length is 80 characters at 10 characters per inch. EIA-RS-232-C interface is standard. Also available in a R/O version.	$1495 (20% discount if purchased in quantities of 100). R/O version: $1295	$17.50/month service rate. $90/monthly (includes maintenance) lease option for a 12 month lease. At the end of the lease period 50% can be obtained towards purchase.
	Model 745: Portable version of 743 with an accoustic coupler	$2095	

Manufacturer	Description	Purchase Costs	Service/Lease Costs
	Model 763: Buffered terminal with bubble memory storage. Standard model provides 20 K characters of bubble memory storage. Additional memory is available in 20 K increments up to 80 K. Print speed is 30 cps. Can be operated at speeds up to 9600 baud.	$2695 Bubble memory expansion (20 K bytes) $500.	$24/month, service charge $125/monthly lease option for a 12 month lease.
	Model 765: Portable version of 763 with an accoustic coupler.	$2995	
	Built in 300 baud modem	$195	$8
Western Union	Model EDT33: KSR or ASR terminal which can operate at 10 cps or 110 baud. Line length is 86 characters with 10 characters per inch.	KSR: $970 ASR: $1290	$49/month $60/month for one-year lease
	EDT33MSR: Includes a magnetic tape buffer with the basic 33 for speeds from 10 to 120 cps.	$2810	$133/month for 1 year lease.
	Model EDT 300: KSR, ASR or MSR configurations. Transmits and receives at 10-15 or 30 cps. Line lengths up to 120 characters.	KSR:3130 ASR:4925 MSR:4880	$115/month $215 month $199/month for 1 year lease.
	Model EDT 1200: Same as EDT 300 but with print speeds up to 120 cps.	KSR:$3610 ASR:$5065 MSR:$5360	$165/month $250/month $249/month for 1 year lease

Manufacturer	Description	Purchase Costs	Service/Lease Costs
	Model EDT 1232: KSR and MSR models can operate at speeds up to 120 cps with 132 print positions per line.	KSR: $3900 MSR: $5075	$175/month $259/month for one-year lease
	Built in 300 baud modem option with an EDT 300	$400	
Anderson-Jacobsen	Model AJ 630: KSR model with print speeds of 10, 15 or 30 cps. Line length can be up to 140 characters at 10 characters/inch. EIA-RS-232C compatible interface available	In quantities of 25-50, purchase cost $1100.	$97/month for a one-year lease.
	Model AJ 860: KSR terminal which can operate at speeds up to 120 cps. Line length is 132 characters.	$2500 for up to 600 baud operation $240 extra for 1200 baud operation.	$100/month with $20/month for 1200 baud operation, for a one-year lease.
	Model AJ 830: Buffered terminal with up to 128 characters input/output receive buffer. Operates at 10, 15 or 30 cps.	$3000 for 30 cps print speed and $3100 with a 45 cps print speed option.	$127/month for a 30 cps print speed and $132/month for a 45 cps print speed, for a one-year lease.
	Model AJ 832: Buffered terminal with 256 character receive buffer. Operates at 10, 15, or 30 cps. Both the AJ 830 and 832 have graphics capability.	$3186 for a 30 cps print speed, and $3286 for a 45 cps print speed	$132/month for a 30 cps print speed, and $137/month for a 45 cps print speed, for a one-year lease

Manufacturer	Description	Purchase Costs	Service/Lease Costs
	Model AJ 730 is a cassette recorder capable of sending/receiving data at switch selectable speeds from 10 to 12 cps. This unit can be used to record messages as well as to prepare and edit data off-line before transmission.	$2115 plus $1000 if an integral 1200 bps modem is included	$113/month plus $45/month if an integral 1200 bps modem is included.
Applied Computer System	Model SA 300: Print speed up to 45 cps. Comes with 4K RAM expandable to 60K Size of receive buffer is program changeable. Communication baud rates are switch selectable from 110 to 4800. Optional capability to add disk storage and edit software.	List price: $4500 with friction feed platen. Pin feed platen $160.	$250/month for a 1 year lease plus $30/month for maintenance.
Xerox	Diablo Hyterm 1620: Communication speeds from 110 to 300 band. Nominal print speed is 45 cps, but built in motion minimization and program controlled backward printing can increase printing speeds. Has graphics capability.	Prices quoted by Applied Computer Systems: $3800 for KSR with Auxiliary Tractor Forms Feed R/O version: $3010	$180/month for a one year lease. R/O: $165/month. $30/month for maintenance

Manufacturer	Description	Purchase Costs	Service/Lease Costs
Datapoint Corporation	Models 3551 and 3552: Keyboard send receive terminal available in 80 or 160 cps with 25-425 lines per minute printing rate. It has a dual separately controlled paper feed, and can transmit keyboard data, at the same time, independently printing data received from the host.	List price: $4395 for the 80 cps version and $4,895 for the 160 cps version.	$150/month for the 80 cps version and $165/month for the 160 cps version on a 3 year lease.

Table 3.2-2

<u>List of Manufacturers for Teleprinter Terminals</u>

Anderson Jacobson, Inc. 521 Charcot Ave. San Jose, CA 95131	(408) 263-8520
Applied Computer Systems 615 N. Mary Ave. Sunnyvale, CA 94086	(408) 733-3733
Centronics Data Computer Corp. Hudson, NH 03051	(603) 883-0111
ComData Corp. 815 N. Monticello Skokie, IL 60076	(312) 677-3900
Computer Devices, Inc. 25 North Ave. P.O.B.421 Burlington, MA 01803	(617) 273-1550
Data Access Systems, Inc. 100 Rte.46 Mountain Lakes, NJ 07046	(201) 335-3322
Data Dynamics Ltd. Springfield Rd. Hayes, Middlesex, UK	(01) 848-9781
Data General Corp. Route 9 Southboro, MA 01772	(617) 485-9100
Data Point Corp. 9725G Datapoint Dr. San Antonio, TX 78284	(512) 699-7059
Data Terminals & Communications 1190 Dell Ave. Campbell, CA 95008	(408) 378-1112
Di/An Controls, Inc. 944 Dorchester Ave. Boston, MA 02125	(617) 288-7700
Digital Equipment Co. Components Group One Iron Way Marlborough, MA 01752	(617) 481-7400

Extel Corporation 310 Anthony Trail Northbrook, IL 60062	(312) 564-2600
GE Data Communication Products Dept. Waynesboro, VA 22980	(703) 942-8161
GEC Telecommunications Ltd. Whinbank Rd., Aycliffe Industrial Est. Darlington DL5 6DA UK	Aycliffe (032 571) 3341
Harris Corp. Data Communications Div. 11262 Indian Trail, P.O.B. 44076 Dallas, TX 75234	(214) 620-4400
IBM 1133 Westchester Ave. White Plains, NY 10604	(914) 696-1900
ITT Business Systems 65 Uxbridge Rd. London W5 UK	(01) 579-9191
LogAbax (U.S. Div.) 10889 Wilshire Blvd. Los Angeles, CA 90024	(213) 477-0494
MI^2 Corporation 1212 Kinnear Rd. Columbus, OH 43212	(614) 481-8131
Olivetti Corp. of America 500 Park Ave. New York, NY 10022	(212) 371-5500
Ing. C. Olivetti & C.S.p.A. via Jervis 77 10015 Ivrea, Italy	(0125) 522639
SAGEM Department Teletransmissions 6, Avenue d'Elena 75783 Paris CEDEX 16 France	747.81.80
SCI Systems, Inc. 8600 S. Memorial Pkwy, P.O.B. 4000 Huntsville, AL 35802	(205) 881-1611
Scope Data, Inc. 3728 Silver Star Rd. Orlando, FL 32808	(305) 298-0500

Siemens AG Telegraph & Signalling Systems Hofmannstrasse 51 Postfach 700072 D8000 Munich 70 W. Germany	(089) 722-1
Siemens Corporation 186 Wood Avenue South Iselin, NJ 08830	(201) 494-1000
Tally Corporation 8301 South St. Kent, WA 98031	(206) 251-5500
Teletype Corporation 5555 Touhy Ave. Skokie, IL 60076	(312) 982-2000
Texas Instruments, Inc. Digital Systems Div. P.O.B. 1444, M/S 784 Houston, TX 77001	(713) 494-5115, ext. 2124
Trans-Lux Corp. 110 Richards Ave. Norwalk, CT 06854	(203) 853-4321
Victor, Business Products Group 3900 N. Rockwell St. Chicago, IL 60618	(312) 539-8200
Western Union Data Services Co. 70 McKee Drive Mahwah, NJ 07430	(201) 529-1170
Xerox Corp. 5300 W. Century Blvd. El Segundo, CA 90245	(213) 277-6565

3.2.2 Future Trends

In recent years teleprinter terminal manufacturers have offered wider carriages (over 130 characters per line), increased buffer capability, and auxiliary input/output capability all at lower costs. Advances in solid state electronics together with innovative printing mechanisms have enabled manufacturers to produce faster more versatile and more operator efficient terminals. Improvements in packaging techniques and reduction in electronic circuit size have resulted in lightweight portable teleprinters. Microprocessor technology has extended the use of a terminal to include off-line data preparation capabilities such as text editing and message batching.

The future impact on the teleprinter industry will be in the area of new communications techniques. Protocols designed by industry giants such as IBM, AT&T and the international CCITT X.25 international protocol will require products to emulate these communication techniques. Currently teleprinter manufacturers offer attractive upgrade alternatives, but remain communications compatible with Teletype and IBM products. Industry is expanding the capabilities of their systems by offering customized designs through more sophisticated peripheral equipment and support by reprogrammable controllers.

In the future we will see terminals flexible enough to operate over different types of lines at different speeds and in a variety of modes including half duplex and full duplex operation. Terminals will be able to accommodate a variety of code formats such as ASCII, BCD, EBCDIC, Baudot and other variations. Error control protocols will become increasingly important and so will the ability to operate unattended after business hours. Increasing amounts of intelligence at the terminal will reduce the flow of data to and from centralized computers reducing operator time and communication costs.

3.3 VIDEO DISPLAY TERMINALS.

3.3.1 General Description and Specifications.

Most of the items discussed above apply in the selection of display terminals as well. Display terminals offer the additional flexibility of repositioning the cursor on the screen which allows easy backspacing and deleting and inserting characters and lines. Another desirable feature in some display terminals is the user's ability to request hard copy selectively. The user can then request a hard copy of only selected portions of the text displayed on the screen. Protected fields also allow specified form structures to be saved while the data in the unprotected fields is erased. Thus in applications requiring filling out a pre-defined form (such as an inventory or sales form) many times, the form structure need not be re-entered each time the form is filled with new data.

Some terminals also provide a polling and addressing capability, which allows a central computer to selectively send and receive messages to and from terminals. Also a central computer can poll individual terminals during off-hours when line costs are low, and collect the messages which were previously entered.

Video display terminal prices range from $800 to $7000. A list of representative terminal costs and descriptions is given in Table 3.3-1. Table 3.3-2 gives a list of video display terminal manufacturers. More information is included in the Appendix which was taken from the New Product Guide Section of the November '78 issue of Interface Age. The appendix also includes a table from the April '78 issue of Telecommunications giving manufacturers' specifications for a variety of display terminals. It is recommended that when a user is ready to select a terminal, they should first consult such articles for the latest update of products, features and prices.

C-2

Table 3.3-1

Parameters for Video Display Terminals

MANUFACTURER	DESCRIPTION	PURCHASE COST	SERVICE/LEASE COSTS
Leer-Siegler Inc.	Model ADM-3A: Basically a dumb terminal with 12" diagonal screen and 1920 character display format (24 x 80). Communication rates from 75 to 19,200 baud with full or half duplex transmit/receive modes	Price ranges from $895 to $1390, depending upon keyboard and interface option used.	$45/month on a 3-yr. lease, with $15/mo. for maintenance.
	Model ADM-1A: CRT terminal, 12" diagonal, 24-line screen. Displays 1920 characters. Transmission speed from 110 to 19,200 baud. Can transmit in conversational or block modes. Two levels of editing options available. Polling and addressing, current loop and RS232C extension, serial printer ports and special character sets available as options.	Price ranges from $1595 to $2817, depending upon options used.	
	ADM-31: A smart terminal with 12" diagonal screen and 1920 character display. Comes with 2-page display as standard. Can transmit in conversational or block modes. Comes with edit capabilities, formatting and protected fields. Polling and addressing and serial printer interface available as an option. Data rates from 50 to 9600 bps.	$1450 with an additional $130 for serial printer port and $130 for polling and addressing.	$61/month on a 3-yr. lease with $20/mo. for maintenance.

MANUFACTURER	DESCRIPTION	PURCHASE COST	SERVICE/LEASE COSTS
Leer-Siegler, Inc. (continued)	Model VDP 400: A minicomputer-based intelligent terminal with 20K to 32K bytes of ROM and 8K to 32K bytes of RAM. 15" diagonal screen with 2000 character display; a 25th display line available for display of terminal status, internal commands, time of day and messages from the host. Comes with standard editing capabilities. Optional features include forms control, four function arithmetic and automatic tabbing. Also available are additional memory, limited graphics, alternate character sets, and a printer port.	Price ranges from $3995 to $5620, depending on options with an additional $2400 for software.	
Teletype	Model 40/1: 24-line display capacity screen with 80 characters/line. Additional 24 or 48 lines of data storage available as an option. Editing capability available. Optional features include line independent tab control, highlighting portions of displayed data, and protected format. Transmission and reception at speeds of 1050, 1200, and 2400 bps. Can operate in batch or conversational mode in half duplex only.	Price ranges from $2940 to $3324, depending on transmission mode, printer port, display memory options and additional features.	
	Model 40/2: Basically the same as Model 40/1, with some additional features like destructive scrolling which allows continuous bottom line reception of data. Line speeds range from 110 to 4800 bps, half or full duplex transmission.	Price ranges from $3214 to $3730.	

MANUFACTURER	DESCRIPTION	PURCHASE COST	SERVICE/LEASE COSTS
Teletype (continued)	Model 40/3: Comes with a programmable controller to enable the terminal to conform to a variety of selective calling procedures. The controller permits stations to be programmed with their own polling and addressing codes. Transmission speeds of 1050, 1200, or 1800 bps. Other optional features are the same as for Model 40/2 with bi-directional scrolling.	Price ranges from \$3458 to \$3773; station controller \$1084.	
	Model 40/4: Can be configured as a single display station or cluster controlled. Operating speeds range from 2400 to 9600 bps, depending on configuration. Station can be arranged from 1 to 36 devices coupled to six device cluster controllers and one station cluster controller. Half duplex operation.	Prices for the keyboard display with a single display controller ranges from \$3350 to \$3676. Prices for the device cluster controller range from \$4770 to \$4806; prices for the station cluster controller range from \$3985 to \$4308. Price for a minicluster controller, which controls 2 displays and 1 printer, range from \$5518 to \$5233. Teletype gives a 10% discount to non-profit educational institutions, public and private, and to governments.	

MANUFACTURER	DESCRIPTION	PURCHASE COST	SERVICE/LEASE COSTS
Texas Instruments	Model 770: An intelligent terminal with processing capabilities based on TI's 16-bit TMS9900 microprocessor. The 770 incorporates a 1920-character display, dual minicartridge magnetic tape units, random access memory expandable to 24K bytes, and a keyboard. An alternate configuration provides a built-in 30 cps, 80-column thermal printer. Also available is application programming capability using TPL 700, a high level language. Options include memory expansion using either an 8K byte or a 16K byte expansion option, graphics kit which provides additional video display character set, internal modem kits, interface kit for external modem, and a terminal polling system.	List prices are: \$6400 w/o thermal printer; \$7500 with thermal printer; additional \$1075 for 16K byte memory expansion and \$150 for graphics kit option. Software kits can run to another \$500.	For a one-year lease, \$220/month w/o printer; \$300/month with printer.
Western Union	Video 100: 1920-character display screen size with data rates selectable from 110 to 19,200 baud, full or half duplex operation. Can be configured as a stand-alone terminal or interfaced with teleprinters or to a magnetic tape cassette buffer.	List price: \$860 discounted to \$770 in quantities above 100.	\$65/month for a one-year lease.
	Video 200: Buffered, interactive, microprocessor-based display terminal with 2000-character display screen. Comes with X, Y cursor positioning and full editing capabilities as well as forms drawing; transmission may be in the character or block mode.	Price ranges from \$1850 to \$1920.	\$100/month for a one-year lease.

Table 3.3-2

List of Manufacturers for Display Terminals

AEG Telefunken Elisabethenstrasse 3 7900 Ulm. W. Germany	
Ann Arbor Terminals, Inc. 6107 Jackson Rd. Ann Arbor, MI 48103	(313) 769-0926
Applied Digital Data Systems, Inc. 100 Marcus Blvd. Hauppauge, NY 11787	(516) 231-5400
Budavox Telecom Foreign 1392 POB 267 Budapest VIII, Hungary	426 549 Telex: 225077
Bunker Ramo Corp. Trumbull Industrial Park Trumbull, CT 06609	(203) 377-4141
Burroughs Corporation Burroughs Place Detroit, MI 48232	(313)972-7267
Computer Optics, Inc. Berkshire Industrial Pk. Bethel, CT 06801	(203) 744-6720
Conrac Corporation, Conrac Div. 600 N. Rimsdale Ave. Covina, CA 91722	(213) 966-3511
Courier Terminal Systems, Inc. P.O.Box 29039 Phoenix, AZ 85038	(602) 244-1392
Custom Terminals Corp. 216 N. Fehr Way Bayshore, NY 11706	(516) 231-3111
Dacoll Engrg. Services Ltd. Dacoll House, Bathgate W. Lothian, England	0506 56565 Telex: 727359

Data General Corp. Route 9 Southboro, MA 01722	(617) 485-9100
Datamedia Corporation 7300 N. Crescent Blvd. Pennsauken, NJ 08110	(609) 665-2382
Data 100 Corporation 6110 Blue Circle Drive Minnetonka, MN 55343	(612) 941-6500
Datapoint Corporation 9725 Datapoint Drive San Antonio, TX 78284	(512) 699-7000
Data Terminals & Communications 1190 Dell Avenue Campbell, CA 95008	(408) 378-1112
Delta Data Systems Corp. Woodhaven Industrial Park Cornwells Heights, PA 19020	(215) 639-9400
Digi-Log Systems, Inc. Babylon Road Horsham, PA 19044	(215) 672-0800
Digital Equip. Corp/OEM Group 1 Iron Way Marlboro, MA 01752	(617) 481-7400
Elta Electronic Ind.Ltd. POB 330 Ashdod, Israel	055 31155 Telex: 031807
GTE Information Systems, Inc. One Stamford Forum Stamford, CT 06904	(Att'n: Mr. Richard Concilio)
Hazeltine Corporation Cuba Hill Road Greenlawn, NY 11740	(516) 261-7000
Hewlett-Packard, Data Terminals Division 19400 Homestead Rd. Cupertino, CA 95014	(408) 257-7000
Honeywell Information Systems,Inc. 200 Smith St. Waltham, MA 02154	(617) 237-4100

Human Designed Systems, Inc. 3700 Market St. Philadelphia, PA 19104	(215) 382-5000
IBM Corp/Data Proc. Div. 1133 Westchester Ave. White Plains, NY 10604	(914) 696-1900
Incoterm Corp. 65 Walnut St. Wellesley, MA 02181	(617) 237-2100
Infoton, Inc. Second Avenue Burlington, MA 01803	(617) 272-6660
Intelligent Systems Corp. 5965 Peachtree Corners East Norcross, GA 30071	(404) 449-5961
Interface Technology, Inc. 10506 Kahlmyer Drive St. Louis, MO 63132	(314) 426-6880
ITT Business Systems Crowhurst Rd., Hollinbury Brighton BN 1 8AN England	0273 507111
Lear Siegler, Inc./EID 714 N. Brookjurst St. Anaheim, CA 92803	(714) 774-1010
Lyme Peripherals Ltd. 2 Avenue Court, Farm Av. London NW2, England	01 452 0490
Megadata 35 Orville Drive Bohemia, NY 11716	(516) 589-6800
NCR Corp/EDP Products Main & K Streets Dayton, OH 45409	(513) 449-2000
Omron Systems, Inc. 432 Toyama Drive Sunnyvale, CA 94086	(408) 734-8400
Ontel Corporation 250 Crossways Park Drive Woodbury, NY 11797	(516) 364-2121

Perry Electronics 2424 Atlantic Avenue Raleigh, NC 27604	(919) 833-2554
Racal-Milgo 8600 N.W. 41st St. Miami, FL 33166	(305) 592-8600
Ramtek 585 N. Mary Ave. Sunnyvale, CA 94086	(408) 735-8400
Raytheon Cossor Data Systems Elizabeth Way, Harlow Essex CM19 5BB, England	N. Harlow 26862
Raytheon Data Systems Corp. 1415 Boston-Providence Turnpike Norwood, MA 02162	(617) 762-6700
Siemens AG PF 832940 D-8000 Munchen 83, England	
Sycor, Inc. 100 Phoenix Drive Ann Arbor, MI 48104	(313) 995-8527
Tano Corporation 4521 W. Napoleon Ave. Metairie, LA 70001	(504) 888-4884
TEC, Inc. 2727 N. Fairview Ave. Tucson, AZ 85705	(602) 792-2230
Tektronix, Inc. Information Display Group P.O.Box 500 Beaverton, OR 97005	(503) 644-0161
Teletype Corporation 5555 Touhy Avenue Skokie, IL 60076	(312) 982-2000
Telex Terminal Communications, Inc. 3301 Terminal Drive Raleigh, NC 27611	(919) 834-5251
Texas Instruments, Inc. Digital Systems Div. P.O.Box 2900 Austin, TX 78769	(512) 258-7314

Volker-Craig Ltd.
266 Marsland Drive
Waterloo, Ont. N2J329
Canada (519) 884-9300

Western Union Data Services
70 McRee Drive
Mahwah, NJ 07430 (201) 529-1170

Westinghouse Canada Ltd.
P.O.Box 510
Hamilton, Ont. L8N 3K2
Canada (416) 528-8811

Wiltek, Inc.
Glover Avenue
Norwalk, CT 06430 (203) 853-7400

Zentec Corporation
2368-C Walsh Avenue
Santa Clara, Ca 95050 (408) 246-7662

3.3.2 Future Trends

Many users are finding the advantage of higher communication speed, better editing capabilities and lower initial costs outweigh the need for hard copy. Many alphanumeric display terminals come with hard copy options such as the Texas Instruments 770 intelligent terminal.

The future will see the growing importance of the microprocessor to give terminals more versatility and intelligence for storing, formatting, etc. at lowered costs. Self diagnostic features will improve maintenance. Better resolution of displays and introduction of color will improve operator-terminal interaction. To reduce space requirements some manufacturers anticipate a switch from CRT to plasma displays. Introduction of built-in modems together with the availability of digital switched lines will remove the requirement for a separate modem at the communication interface. More manufacturers are starting to offer features such as: ability to customize to users' requirements; detachable keyboards; multi-language capability; greater compatibility; larger buffers; off-screen storage.

3.4 RECEIVE ONLY PRINTERS.

3.4.1 General Description and Specifications.

Receive only printers are normally used to provide hard copy printout of information displayed on a CRT terminal or as an output peripheral in batch processing applications.

Many of the teleprinters discussed previously can be configured as receive only terminals without a keyboard send capability. Printer costs vary according to print speed, print mechanism, choice of typefaces and fonts, choice of interfaces, print buffer, graphics capability and choice of character codes. RO printer costs vary from $1000 to $4000. Table 3.4-1 gives the costs and description of some representative RO printer models while Table 3.4-2 gives a list of manufacturers. The appendix includes a table from the February '78 issue of Telecommunication which gives a list of manufacturers' specifications for a variety of RO printers.

Table 3.4-1

Parameters for Receive-Only Printers

MANUFACTURER	DESCRIPTION	PURCHASE COST	LEASE/SERVICE COST
Digital Equipment Company	Model LA180: A medium speed hard-copy printer capable of producing 132 columns of type at 180 cps. The printer recognizes seven control commands and the character information in the form of 7-bit ASCII codes. Equipped with a standard 8-bit parallel interface with a serial interface option. Accommodates up to six-part paper forms and handles variable form widths from 3 to 14 7/8 inches.	$3240, list price	$50/month maintenance.
Integral Data Systems	Model IP 125 or 225 available as friction feed or tractor feed, respectively. Microprocessor controlled with RS232C serial interface and TTL level parallel interface. Line lengths of 80 columns as standard. Serial baud rate to 1200 bps with a multiple line buffer of 256 characters. Instantaneous print rate to 100 cps with a sustained throughput of 50 cps. Multiple copy capability, uses full 8.5" width paper. Optional features include line lengths to 132 columns, instantaneous print rate to 165 cps with sustained throughput to 80 cps. Print densities of 8.3, 10, 12, and 16.5 characters/inch, and full CRT screen size buffer of 2048 characters. Special graphic symbols, graphic dot plotting mode, and variable size available as options.	IP 125: $799 IP 225: $949 Options can cost up to $485. 22% discount available on quantities above 100.	

MANUFACTURER	DESCRIPTION	PURCHASE COST	LEASE/SERVICE COST
Sanders Technology	Media 12/7: Print speed is a function of type size, desired quality and speed of the print head. The print head is a seven-wire matrix head and travels at 12 inches/second. Thus, print speed varies from 36 cps for a four-pass, 12-pitch typeface up to 216 cps for a single pass, 18-pitch typeface. Capability to mix typefaces. One fully formed typeface in 10 or 12 pitch and one high speed matrix face are included in the standard model. Up to 56K bytes of storage are available for typefaces, graphic images or forms storage. Graphic images such as signatures, letterheads, logos and sketches may be digitized, electronically stored and printed. Both serial and parallel interfaces are available as standard features.	Unit price: $4000 For quantities between 100 to 500: $2010.	
Lear Siegler Inc.	Model 200A Series Ballistic Printer: Prints at 180 cps bidirectional printing. Can use paper widths up to 15 inches with 132 columns at 10 characters/inch. Comes with built-in microprocessor control and a character buffer optionally expandable to 1024 characters. Can be configured with either a serial or parallel data interface. Options include audible alarm, additional memory, 12-pitch font.	Parallel model 201A: $2895. Serial model 210A: $2995. Options add up to $315.	

MANUFACTURER	DESCRIPTION	PURCHASE COST	LEASE/SERVICE COST
Teletype	Model 40 printers consist of line-at-a-time friction and tractor feed printers. The friction feed version prints an 80-character line on a 8.5-inch paper. 132 column printing is available with the tractor feed model, with adjustable tractors to accommodate forms 4.125 to 15 inches wide. The tractor feed models include options that accept forms 2.5 to 22 inches in length. Printing speed is 300 lines per minute. Choice of interface includes simplified EIA which provides character-at-a-time data transfer at speeds from 150 to 9600 bps, a standard serial interface and a conversion kit for parallel interface.	List price ranges from $1506 to $1878, depending on the printer feed mechanism, maximum line length, and printer character set. A 10% functional discount is available to non-profit educational institutions, public and private, and to governments.	
Texas Instruments	Model 810 is a multicopy, impact printer controlled by an on-board microprocessor to effect bidirectional printing. Printing speed is 150 cps with an effective throughput from 60, 132 character lines/minute up to 440 lines/minute with an average of 10 character lines. Standard features include adjustable tractor feeds 3 to 15 inches, EIAR232C serial interface, switchable speeds from 110 to 9600 baud, one vertical form program, one programmable forms length. Optional features include full ASCII character set, vertical forms control, form length control and compressed character printing with a 16.5 character/inch print density.	Unit list price: $1895. Options can add up to $600.	$110/month for a 12-month lease.

MANUFACTURER	DESCRIPTION	PURCHASE COST	LEASE/SERVICE COST
Hewlett-Packard	Model 2608A: A dot metrix,132 character position, 400 lpm printer. Microprocessor control provides self diagnostics and makes possible a variety of character and graphic print modes. As many as 16 character sets can reside within the printer. Standard is 128 character ASCII. The printer can be programmed to produce characters of double normal size. It can plot any graphic display that can be described by a metrix of dots with a density of 5040 dots per square inch.	$9250.	

Table 3.4-2

List of Manufacturers for R/O Printer Terminals

Anadex, Inc. 9825 DeSoto Ave. Chatsworth, CA 91311	(213) 998-8010
Centronics Data Computer Corp. One Wall St. Hudson, NH 03051	(603) 883-0111
Computer Devices, Inc. 9 Ray Ave. Burlington, MA 01803	(617) 273-1550
Computer Terminal Systems, Inc. 52 Newtown Plaza Plainview, NY 11803	(516) 293-6611
Cossor Electronics Ltd. The Pinnacles, Elizabeth Way Harlow, Essex, England	027-926-862
Data 100 Corp. 25 Graystone St. Warwick, RI 02886	(612) 941-6500
Data Products Corp. 6219 DeSoto Ave. Woodland Hills, CA 91364	(213) 887-8000
Data Royal, Inc. 235 Main Dunstable Rd. Nashua, NH 03060	
Data Terminals and Communications 1190 Dell Ave. Campbell, CA 95008	(408) 378-1112
Decision Data Corp. 100 Witmer Rd. Horsham, PA 19044	(215) 674-3300
Diablo Systems, Inc. Xerox Co. 24500 Industrial Blvd. Hayward, CA 94545	(415) 783-3910
DI/AN controls, Inc. 944 Dorchester Ave. Boston, MA 02125	(617) 288-7700

Digital Equipment Corp. One Iron Way Marlborough, MA 01752	(617) 481-7400
Epson America, Inc. 2990 West Lomita Blvd. Torrance, CA	(213) 378-2220
EXTEL Corp. 310 Anthony Trail Northbrook, IL 60062	(312) 564-2600
Facit-Addo, Inc. 501 Winsor Drive Secaucus, NJ 07094	(201) 866-5111
Florida Data Corp. 3308 New Haven Ave. W. Melbourne, FL 32901	
General Electric Co. Data Communications Div. Waynesboro, VA 22980	(703) 942-8161
Hewlett-Packard Co. 1501 Page Mill Rd. Palo Alto, Ca. 94304	(415) 493-1501
Houston Instrument 8500 Cameron Rd. Austin, TX 78753	(512) 837-2820
Integral Data Systems, Inc. 14 Tech Circle Matick, MA 01760	(617) 237-7610
Keinzle Apparate Gmbh D-7730 Villengen W. Germany	
Lear Siegler, Inc. 714 N. Brookhurst St. Anaheim, CA 92803	(714) 774-1010
MI^2 Corp. 1212 Kinnear Rd. Columbus, OH 43212	(614) 481-8131
NEC Information Systems, Inc. 5 Militia Drive Lexington, MA 02173	(617) 862-6410

Philips' Telecommunicate Industrie B.V.
Kumerlingh Onnesweg POB 32
Hilversum, The Netherlands

Practical Automation, Inc.
Trap Falls Rd.
Shelton, CT 06484 (203) 929-5381

Printronix, Inc.
17935 Sky Park Circle
Irvine, CA 92707 (714) 549-8272

Randal Data Systems
2807-F Oregon Court
Terrance, CA 90503

R. C. Sanders Technology Systems, Inc.
5 Tinkham Avenue P.O.B. 324
Derry, NH 03038 (603) 434-1571

SCI Systems, Inc.
8600 S. Memorial Pky.
Huntsville, AL (205) 881-1611

Scope Data, Inc.
3728 Silver Star Rd.
Orlando, FL 32808 (305) 298-0500

Siemens Corp.
186 Wood Ave. South
Iselin, NJ 08830 (201) 494-1000

Tally Corp.
8301 South 180th St.
Kent, WA 98031 (206) 251-5500

Teletype Corp.
5555 Touhy Ave.
Skokie, IL 60076 (312) 982-2000

Texas Instruments, Inc.
PO Box 1444
Houston, TX 77001 (713) 494-5115

Tycom Systems Corp.
26 Dust Rd.
Fairfield, NJ 07006 (201) 227-4141

Versatec, Inc.
2805 Bowers Ave.
Santa Clara, CA 95051 (408) 988-2800

Western Union Data Services
70 McKee Drive
Mahwah, NJ 07430 (201) 529-1170

Xerox Corp.
5300 W. Century Blvd.
El Segundo, CA 90245 (213) 277-6565

Additional Information on Data Terminals

Table 3.4-3: DISPLAY TERMINAL FEATURES
(from Nov. 1978 issue of INTERFACE)

Terminals

ADM-31 CRT Terminal

The ADM-31 is a new low-cost video display terminal featuring two pages of memory, function keys and complete editing capabilities. The smart terminal offers the user two full 1920 character pages of display with independent page characteristics of Protect, Write/protect, Program mode and Cursor retention.

The microprocessor-based ADM-31 is completely self-contained and comes equipped with keyboard, control logic, character generator, refresh memory and interface. The terminal's keyboard is integrated with main logic and can generate a full 128 ASCII character set.

Single quantity price is $1,450. For more information contact Lear Siegler, Inc./Data Products Div., 714 N. Brookhurst, Anaheim, CA 92803, (800) 854-3805 and in California (714) 774-1010.

CIRCLE INQUIRY NO. 435

APL/ASCII Video Terminal

The Elite 3045A is a low-cost, microprocessor-based fuly buffered APL/ASCII video terminal. This new video terminal with transaction processing capability offers protected formats, video enhancements and APL overstrike/ASCII underscore.

The 3045A also features asynchronous and optional isochronous communications interfaces; 103 and 202 modem compatibility and switch-selectable EIA and optional 20 mA current loop interfaces.

Single quantity price is $1,995 and $1,520 in quantities of 100. Delivery is 60 days ARO. For more information contact Datamedia Corp., 7300 N. Crescent Blvd., Pennsauken, NJ 08110, (609) 665-2382.

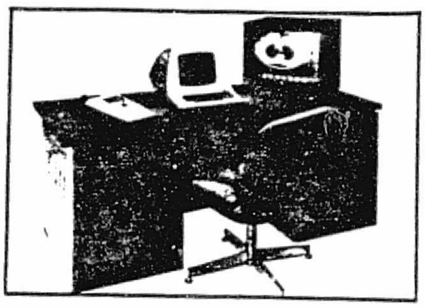
CIRCLE INQUIRY NO. 430

RM-3000 Series Independent Display System

The RM-3000 IDS is a new, complete fmaily of stand alone imaging and graphics systems in color, gray scale, and black and white. The unit is designed for stand-alone, off-line processing in virtually any graphics or display application.

The 3000 IDS is based on the RM-9000 or RM-9050 Series display controllers and DEC's LSI-11 microprocessor. Display data can be processed from a number of different sources such as floppy disk, magnetic tape, disk packs, telecommunication links or directly from a host computer via modem control.

The basic RM-3000 IDS system includes an LSI-11 microcomputer with 64K bytes of RAM, floating point arithmetic, system monitoring unit, serial interface, dual floppy disk system, RM-9000 or 9050 Series display controller,



TR-11 I/O driver and a 48" or 72" desk console. U.S. prices start at $18,200 with a 90-day delivery. For more information contact Ramtek Corp., 585 No. Mary Ave., Sunnyvale, CA 94086, (408) 735-8400, Mrs. Beverly Toms.

CIRCLE INQUIRY NO. 440

Smart CRT Terminal

The ADM-42 is a low-cost video display terminal that comes standard with two 1920 character pages of memory that can be optionally expanded in two page increments to eight full pages. The unit features total flexibility of format, editing, interface and transmission.

All pages have independent Protect, Write/protect, Program mode and Cursor retention. The ADM-42 features a detachable keyboard with upper and lower case, numerics, punctuation, control, numeric keypad and 16 function keys as standard.

For more information contact Lear Siegler, Inc./Data Products Div., 714 N. Brookhurst, Anaheim, CA 92803, (800) 854-3805 and in California (714) 774-1010.

CIRCLE INQUIRY NO. 436

Megraphic 5014

The Megraphic 5014 Refresh Graphics Terminal is designed to replace and to be upwardly-compatible with the Tektronic 4014 storage tube terminal. The 5014, with the proprietary software module EMUTEK™, is totally compatible with the 4014 and offers several major advantages.

Because it is a refresh sytem, the 5014 has the capability to display movement. Local translation, scale, zoom, selective erase, rotation and more are all possible with the 5014, but not with the 4014. Selective erase eliminates the need for the host computer to retransmit an entire picture to change one vector.

The 5014 is fully compatible with Tektronix TCS Plot 10™ and other software developed for Tektronix. With EMUTEK, the 5014 not only emulates the 4014, but also enables use of control codes not available on the Tektronix. This provides the additional benefits inherent in powerful vector refresh systems.

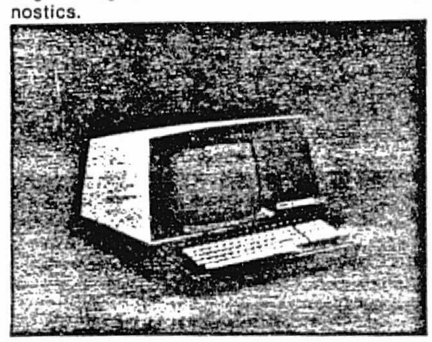
Megatek's modular approach to the manufacture of its equipment allows any 5014 user to expand easily to the Megraphic 5000 Refresh Graphics System at any time merely by adding memory and local storage peripherals.

For more information contact Megatek Corp., Corrento Valley Industrial Park, 3931 Sorrento Valley Blvd., San Diego, CA 92121.

CIRCLE INQUIRY NO. 437

Micro Bee 1

The Micro Bee 1 is an 8085A microprocessor-controlled video display terminal offering the latest advances in technology and human engineering. The machine features self-diagnostics.



The status line is used extensively by the Micro Bee 1 system firmware to display modes of operation, error messages, and communication protocol data as well as a status message showing all switch configurations.

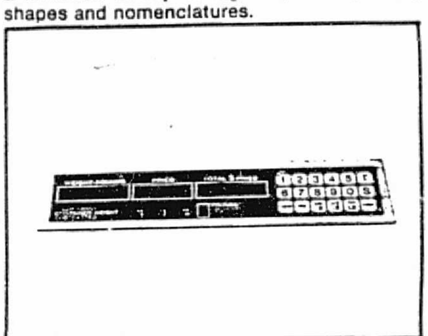
Visual features of the Micro Bee 1 include normal, reverse, blink, underline, and half intensity video levels.

List Price is $1395. For more information contact Beehive International, 4910 Amelia Earhart Dr., Salt Lake City, UT 84125, (801) 355-6000.

CIRCLE INQUIRY NO. 372

Flat-Surface, Tactile Response Custom Keyboards

Tactile feed-back keyboards, customized to each buyer's specifications, are available with a limitless variety of legends, colors, sizes, shapes and nomenclatures.



The new keyboards are available for every industry presently considering or using conventional or soft-touch keyboards. Among possible uses are data entry devices, test instruments, appliances llek microwave ovens and televisions, communications equipment and much more.

The keyboards feature flat, spill-resistant surfaces designed for ease of maintenance. Designed for any configuration from a basic keyboard to total systems that include LEDs or other electronic components, the custom keyboards also feature sealed mounting to insure high reliability.

For more information contact Bowmar Instrument Corp., Commercial Products Div., 8000 Bluffton Rd., Fort Wayne, IN 46809.

CIRCLE INQUIRY NO. 425

The Writehander™ Keyboards

The Writehander is a one-handed keyboard for computers, terminals, displays and other 128 character ASCII or ISO coded devices and is available in both right and left hand configurations in large and small sizes.

The new model features snap-action switches, improved circuitry, and Keypressed signals as well as Strobe pulses to signal that data are available.

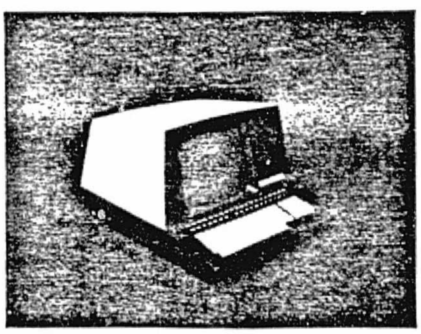
As supplied by the manufacter, the device is ready to connect and use. Five volt, 52 mAdc power is obtained from the inputted terminal. The Writehander is provided with a ribbon cable that has lines for the 7-bit code, high and low 1-bit fixed parity, high and low Strobe and Keypressed signals and the power and common lines.

Delivery is stock to 39 days. For more information contact the NewO Company, 246 Walter Hays Dr., Palo Alto, CA 94303, (415) 321-7979, Sid Owen.

CIRCLE INQUIRY NO. 438

Micro Bee 2

The Micro Bee 2 is an 8085A microprocessor-controlled buffered video display terminal. Numerous features have been tailored to address both interactive and batch mode markets.



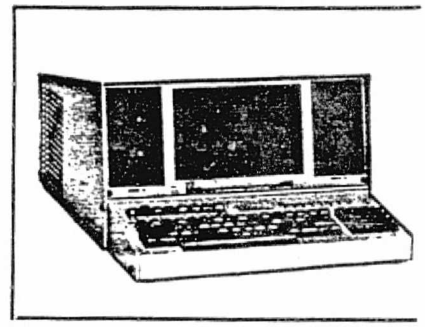
The Micro Bee 2 has a 25th line which dis-tinct from the rest of the display memory and is used as a "status" line. The system firmware displays modes of operation, error messages, and communication protocol as well as terminal status messages on the status line. Standard visual attributes include normal, reverse, blink, underline and half-intensity video levels. These are further enhanced by the addition of logical attributes which include protected data fields, and numeric only fields, as well as modified data field transmission.

List price for Micro Bee 2 is $1695. For more information contact Beehive International, 4910 Amelia Earhart Dr., Salt Lake City, UT 84125, (801) 355-6000.

CIRCLE INQUIRY NO. 424

Processor Terminal

The new Processor Terminal series, desig nated the TEI PT208, is a complete and self contained computer system with display, disk storage, a full keyboard and 8-slot motherboard



It may be used either as a stand alone prc cessor or as a processor terminal in a large system. Features of the PT208 include a 9 high-resolution monitor, a full upper and lowe case ASCII keyboard with eight user-desic nated special function keys and a 16-ke numeric cluster pad. Two Shugart SA-400 min floppy disk drives are standard. The 8-slc mainframe contains a CPU board that feature an 8080 processor and a special circuit that im plements a start up "jump to" routine to an user selected byte address.

Price of the Model PT208 fully assemble and tested is $4,695. For more informatin cor tact CMC Marketing Corp., 5601 Bintliff, Suit 515, Houston, TX 77036, (713) 783-8880.

CIRCLE INQUIRY NO. 426

Table 3.4-4: MANUFACTURERS' SPECIFICATIONS FOR VIDEO DISPLAY TERMINALS
(from April '78 issue of TELECOMMUNICATION)

COMPANY	MODEL	I/O	TRANS. RATE	COMPATIBILITY	CONFIGURATION	SYNCH/ ASYNCH	CRT SIZE-MAX CHAR	FORMAT	CHAR. SET
AEG TELEFUNKEN	TERMINAL 52	HD/FD	50-38.4k bps	CCITT V.24	BOTH	ASYNCH	1920	24x80	ASCII (128)
ANN ARBOR	400 E	HD/FD	100-9600 bps	TTY	STAND-ALONE	SYNCH	1920	24x80	ASCII (128) TTY
APPLIED DIGITAL DATA SYSTEMS	100	HD/FD	TO 19.2k BAUD	TTY/RS-232C	STAND-ALONE	SYNCH	1920	24x80	ASCII (96)
	200	HD/FD	TO 19.2k BAUD	TTY/RS-232C	STAND-ALONE	SYNCH	1920	24x80	ASCII (128)
BUDAVOX	ADP-1500	HD/FD	50-19.2k BAUD	TTY/CCITT V.24	BOTH	ASYNCH	1920	24x80	ASCII (128)
	(OPTIONAL)	HD/FD	50-19.2k BAUD	TTY/CCITT V.24	BOTH	ASYNCH	1440	20x72	ASCII (128)
BUNKER-RAMO	90	HD/FD	1.2k-9.6k BAUD	3270/UNIVAC/ BURROUGHS	BOTH	BOTH	1920	24x80	ASCII (96) E BCDIC
BURROUGHS CORPORATION	TD-730	HD	9.6k-38.4k bps	VARIOUS	STAND-ALONE	BOTH	480	12x40	ASCII (128)
	TD-830	HD	9.6k-38.4k bps	VARIOUS	STAND-ALONE	BOTH	2000	24x80	ASCII (128)
COMPUTER OPTICS	CO: 8277	HD	2k-2.4k bps	CO: 77 IOS	BOTH	SYNCH	1920	24x80	EBCDIC/ASCII (96)
CONRAC	480	HD/FD	110-9.6k BAUD	TTY/BURROUGHS/ UNIVAC/IBM	STAND-ALONE	BOTH	2000	25x80	ASCII (64)
COURIER TERMINAL SYSTEMS, INC.	270	HD	9600 BAUD	IBM	BOTH	SYNCH	3440	43x80	ASCII (96)
CUSTOM TERMINALS CORP.	TR-10	HD/FD	110-9.6k BAUD	TTY/RS-232C	BOTH	SYNCH	16/32	1x32	ASCII (128)
DACOLL ENGRG. SERVICES LTD.	M 241	HD	110-4.8k BAUD	TTY/CCITT V.24	STAND-ALONE	ASYNCH	1920	24x80	ASCII (96)
	M247	HD/FD	110-9.6k BAUD	TTY/CCITT V.24	BOTH	BOTH	2000	25x80	ASCII (96)
DATA GENERAL CORPORATION	6052	FD	TO 19.2k bps	RS-232C	CLUSTER	ASYNCH	1920	24x80	ASCII (64)
	6053	FD	TO 19.2k bps	RS-232C	CLUSTER	ASYNCH	1920	24x80	ASCII (96)
DATAMEDIA CORP.	ELITE 1521A	HD/FD	50-9600 bps	TTY	STAND-ALONE	ASYNCH	1920	24x80	ASCII (128)
	3025	HD/FD	TO 9600 bps	TTY	STAND-ALONE	BOTH	1920	24x80	ASCII (128)
DATAPOINT	3600	FD	1200 BAUD	RS232 C	CLUSTER	ASYNCH	1920	24x80	ASCII (96)
	3610	FD	110-9600 BAUD	RS232 C	CLUSTER	ASYNCH	1920	24x80	ASCII (96)
DATA TERMINALS AND COMMUNICATIONS	382	HD/FD	TO 1200 BAUD	RS-232C	STAND-ALONE	ASYNCH	1920	24x80	ASCII (128)
DATA 100 CORP.	82	HD	TO 9.6k bps	IBM	CLUSTER	SYNCH	1920	24x80	ASCII (96)
	85	HD/FD	56k bps	IBM/UNIVAC/ CDC/HONEYWELL BURROUGHS	CLUSTER	SYNCH	1920	24x80	ASCII (96)
DELTA DATA SYSTEMS CORP.	4100	HD/FD	9600 bps	IBM	CLUSTER	BOTH	2000	25x80	ASCII (224)
	6500	HD/FD	9600 bps	IBM	STAND-ALONE	BOTH	2000	25x80	ASCII (224)
DEC COMPONENTS GROUP	VT52	HD/FD	960 bps	VARIOUS	STAND-ALONE	ASYNCH	1920	24x80	ASCII (96)
DIGI-LOG SYSTEMS, INC.	TELE-COMPUTER II	HD/FD	50-9600 BAUD	TTY	STAND-ALONE	ASYNCH	1280	16x80	ASCII (64)
	MICROTERM II	HD/FD	TO 9600 BAUD	PROGRAMMABLE	STAND-ALONE	BOTH	1920	24x80	ASCII (128)
ELTA ELECTRONIC INDUSTRIES LTD.	8504	HD/FD	110-9.6k	TTY/RS-232	STAND-ALONE	BOTH	1920	24x80	ASCII (96)
HAZELTINE CORP.	1500	HD/FD	110-19.2k bps	TTY	STAND-ALONE	ASYNCH	1920	24x80	ASCII (96)
	1510	HD/FD	110-19.2k bps	TTY	STAND-ALONE	ASYNCH	1920	24x80	ASCII (96)
	MODULAR ONE	HD/FD	110-9600 BAUD	TTY, BURROUGHS, BURROUGHS/UN-IVAC/HONEYWELL	STAND-ALONE	ASYNCH	1920	24x80	ASCII (96)
HEWLETT-PACKARD	2645 A	HD/FD	110-9600 BAUD	RS-232C	STAND-ALONE	BOTH	1920	24x80	ASCII (64)
	2648 A	HD/FD	110-9600 BAUD	RS-232C	STAND-ALONE	BOTH	1920	24x80	ASCII (128)
	2649 A	HD/FD	110-9600 BAUD	RS-232C	STAND-ALONE	BOTH	1920	24x80	ASCII (128)
HONEYWELL INFORMATION SYSTEMS	7205	HD/FD	75-9600 BAUD	RS-232C	STAND-ALONE	ASYNCH	1920	24x80	ASCII (95)
	7200	HD/FD	75-9600 BAUD	RS-232C	STAND-ALONE	ASYNCH	1920	24x80	ASCII (64)
HUMAN DESIGNED SYSTEMS, INC.	CONCEPT 100	HD/FD	50-9600 bps	RS-232C	STAND-ALONE	ASYNCH	1920	24x80	ASCII (128)
	CONCEPT APL	HD/FD	50-9600 bps	RS-232C	STAND-ALONE	ASYNCH	1920	24x80	APL/ASCII (128)
IBM	3270	HD/FD	TO 9600 bps	360/370	CLUSTER	SYNCH	3440	43x80	ASCII/EBCDIC
INCOTERM CORP.	SPD 15/25	HD/FD	75-9600 bps	IBM/UNIVAC/ BURROUGHS/ HONEYWELL	STAND-ALONE/ DUAL	BOTH	1920	24x80	ASCII (64-128) EBCDIC (64)
	SPD 20/20	HD/FD	75-9600 bps	IBM/UNIVAC/ BURROUGHS/ HONEYWELL	CLUSTER	BOTH	1920	24x80	ASCII (64, 128) EBCDIC (64)
	SPD 10/25	HD/FD	75-9600 bps	IBM/UNIVAC/ BURROUGHS/ HONEYWELL	STAND-ALONE/ DUAL	BOTH	1920	24x80	ASCII (64, 128) EBCDIC (64)

COMPANY	MODEL	I/O	TRANS. RATE	COMPATIBILITY	CONFIGURATION	SYNCH/ ASYNCH	CRT SIZE-MAX CHAR	CRT SIZE-MAX FORMAT	CHAR. SET
INFOTON	200 400	HD/FD HD/FD	50-19.2k bps 50-19.2k bps	RS-232C RS-232C	STAND-ALONE STAND-ALONE	ASYNCH ASYNCH	1920 2000	24x80 25x80	ASCII (64) ASCII (128)
INTELLIGENT SYSTEMS CORP.	8001 G	HD/FD	TO 9600 BAUD	RS-232C	STAND-ALONE	ASYNCH	3840	48x80	ISA (64) & COLORS
INTERFACE TECHNOLOGY, INC.	736	HD/FD	110-1200 BAUD	RS-232C/TTY	STAND-ALONE	ASYNCH	8-16	1x16	ASCII (38)
ITT BUSINESS SYSTEMS	3230	HD/FD	———	IBM	STAND-ALONE/ CLUSTER	SYNCH	1920	24x80	ASCII/EBCDIC
LEAR SIEGLER ELECT. INST. DIV.	ADM-3A VDP-400	HD/FD HD/FD	75-19.2k BAUD 75-9.6k BAUD	RS-232C/TTY RS-232C/TTY	STAND-ALONE STAND-ALONE	ASYNCH BOTH	960 1920	12x80 24x80	ASCII (64) ASCII (128)
LYME PERIPHERALS LTD.	4600	HD/FD	75-9.6k bps.	TTY/RS-232C	STAND-ALONE	BOTH	1760	22x80	ASCII (64-96)
MEGADATA CORP.	MC 77 700 S SiR 1000	HD/FD HD/FD FD	TO 38.4k BAUD TO 9600 bps 150-9600 BAUD	RS-232 IBM/UNIVAC/TTY IBM/DSN	BOTH STAND-ALONE STAND-ALONE	BOTH BOTH ASYNCH	1920 1920 960	24x80 24x80 24x40	ASCII (128) ASCII (TO 128) ASCII (96)
NCR CORP., EDP PRODUCTS	796-501 7200-1	HD HD/FD	9600 bps 1200 BAUD	NCR TTY	STAND ALONE STAND-ALONE	SYNCH ASYNCH	1920 512	24x80 16x32	ASCII (96) ASCII (128)
OMRON ELECTRONICS, INC.	8030 8035	HD/FD HD/FD	TO 9600 BAUD 110-9600 BAUD	RS-232C RS-232C	BOTH BOTH	ASYNCH BOTH	1920 1920	24x80 24x80	ASCII (128) ASCII (128)
ONTEL CORP.	OP-I/R	HD	110-19.2k BAUD	———	CLUSTER	———	———	———	ASCII (128)
PERRY ELECTRONICS, INC.	9700 POS	FD	1.2k-9.6k BAUD	RS-232	CLUSTER	ASYNCH	1280	16x80	ASCII (64)
RACAL-MILGO, INC.	40+ 400	HD HD	1.2k-2.4k bps TO 9600 bps	TTY HONEYWELL/ UNIVAC/IBM	CLUSTER STAND-ALONE	BOTH BOTH	1920 1920	24x80 24x80	ASCII (128) ASCII (64-127)
RAMTEK CORP.	MICROGRAPHIC	HD/FD	50-9600 BAUD	RS-232C/TTY	STAND-ALONE	ASYNCH	2000	25x80	ASCII (128)
RAYTHEON COSSOR DATA SYSTEMS	UNITEL FOUR	HD/FD	TO 9.6k bps	RS-232C/V.24	STAND-ALONE	BOTH	2080	26x80	ASCII (93)
RAYTHEON DATA SYSTEMS CO.	PTS-100	HD/FD	20-2400 bps/ 4800 BAUD MAX.	RS-232C/IBM/ TTY	BOTH	SYNCH	1920	24x80	ASCII (128)
SIEMENS	8162 8161	HD HD/FD	230.4k bps OR 9.6k bps .6k-19.2k bps OR 230.4k bps	SIEMENS 7000/ 4004 OR TD 960 SIEMENS 7000/ 4004 OR TD 960	CLUSTER CLUSTER	ASYNCH BOTH	1920 1920	24x80 24x80	CCITT =5 (120) CCITT =5 (95)
SYCOR, INC.	290 405 445	HD HD/FD HD	1.2k-9.6k bps 1.2k-9.6k bps TO 9.6k bps	IBM IBM IBM	CLUSTER CLUSTER CLUSTER	SYNCH BOTH BOTH	1920 1920 2000	24x80 24x80 25x80	ASCII/EBCDIC ASCII/EBCDIC ASCII/EBCDIC
TANO CORP.	OUTPOST 7	HD/FD	110-9600 bps	RS-232C/TTY	STAND-ALONE	BOTH	1920	24x80	ASCII (96)
TEC, INC.	70 500 1440	HD/FD HD/FD HD/FD	50-9600 BAUD 50-9600 BAUD 50-9600 BAUD	TTY-HONEYWELL TTY TTY	STAND-ALONE STAND-ALONE STAND-ALONE	BOTH ASYNCH ASYNCH	2000 2000 1920	25x80 25x80 24x80	ASCII (128) ASCII (128) ASCII (64)
TEKTRONIX, INC.	4024 4025	FD FD/HD	9600 BAUD 9600 BAUD	RS 232/IBM RS 232/IBM	BOTH BOTH	ASYNCH BOTH	2720 2720	34x80 34x80	ASCII (128) ASCII (128) EBCDIC
TELETYPE CORP.	40/4	HD	2.4k-4.8k bps	RS-232C	STAND-ALONE	SYNCH	1920	24x80	ASCII (64) EBCDIC
TELEX TERMINAL COMMUNICATIONS	275 277	HD HD	1.2k-4.8k bps [illegible]k-9.6k bps	RS-232C RS-232C	STAND-ALONE CLUSTER	SYNCH SYNCH	1920 1920	24x80 24x80	ASCII (96) EBCDIC ASCII (96) EBCDIC
TEXAS INSTRUMENTS	770 911	HD/FD HD/FD	2.4k-4.8k bps 2.4k-4.8k bps	IBM/TTY IBM/TTY	STAND-ALONE CLUSTER	BOTH BOTH	1920 1920	24x80 24x80	ASCII (96) EBCDIC ASCII (96) EBCDIC
VOLKER-CRAIG LTD.	404 414	HD/FD HD/FD	TO 19.2k BAUD 110-19.2k BAUD	TTY/RS-232C CCITT-V.24 TTY/RS-232C CCITT-V.24	STAND-ALONE STAND-ALONE	ASYNCH ASYNCH	1920 1920	24x80 24x80	ASCII (128) ASCII (128)
WESTINGHOUSE CANADA LTD.	1625	HD/FD	TO 9600 BAUD	RS-232C	STAND-ALONE	BOTH	1920	24x80	ASCII (64-128)
WILTEK	HAZELTINE 2000	HD	1200, 2400 bps	IBM	BOTH	SYNCH	1998	27x74	ASCII (96)
ZENTEC	ZMS-50 ZMS-70	HD/FD HD/FD	110-9.6k bps 125k bps	RS-232C RS-232C	STAND-ALONE STAND-ALONE	BOTH BOTH	1920 1920	24x80 24x80	ASCII (96) ASCII

Table 3.4-5: SPECIFICATIONS FOR RO PRINTERS
(from Feb '78 issue of TELECOMMUNICATION)

COMPANY & MODEL	PRINT TYPE & METHOD: LINE	SERIAL	IMPACT	NON-IMPACT	PRINT TECHNIQUE	MATRIX SIZE	CHARS/ LINE	FORMS FEED	PRINT SPEED	REMARKS
Anadex Inc. DP — 750A Series		X	X		Drum	FF char.	21	Friction	25 cps	8-line buffer; Form feed for label printing (opt.)
Centronics 6000 Series	X		X		Belt	FF char.	132	Tractor	75-1100 lpm	
Microprinter P1 — Parallel Interface		X		X	Electrosensitive	5x7	20, 40, 80	Friction	240 cps	One line buffer
S1 — Serial Interface		X		X	Electrosensitive	5x7	20, 40, 80	Friction	50-9600 baud	192 char FIFO buffer
100, 300, 500 Series		X	X		Dot Matrix	5x7 9x7	80-132	Tractor	88-330 cps	132/80 char buffer
700 Series		X		X	Dot Matrix	5x7 to 9x9	20/80/132	Tractor Friction Sprocket Front Feed	60-180 cps (761, 300 baud)	256 char buffer on Model 761
Computer Devices Miniterm 1201		X		X	Thermal	5x7	80	Friction	30 cps	2k or 4k FIFO buffer optional
Computer Terminal Systems Various		X	X		Drum	FF	Variable	Friction	15-50 cps	One column buffer. Options, current loop, RS-232
Cossor Electronics Ltd. CGT 1148		X	X		Dot Matrix	9x7	80	Friction	120 cps	Designed for harsh environments. KSR/ASR versions available.
Data 100 2422/9	X		X		Chain	FF	132	Tractor	125 lpm	(1) Whisper cabinet, 6/8 LPI spacing, char. sets optional.
2423/9	X		X		Chain	FF	132	Tractor	250 lpm	(2) Communicates with IBM Bisync 2780 protocol. All models, 1 line buffer
2424/9	X		X		Chain	FF	132	Tractor	300 lpm	
5560/9	X		X		Chain	FF	132/136	Tractor	600 lpm	
Data Royal, Inc. IPS 7000		X	X		Dot Matrix	5x7 9x7 (opt)	132	Tractor Sprocket	120-165 cps	200 char (min.) buffer bidirectional printing. Firmware packages for application flexibility
Data Products Corp. T 80	X		X		Thermal	FF	80	Friction	80 cps	1-line buffer; R232 Interface
M200	X	X			Dot Matrix	7x7	132	Tractor	320 cps	1-line buffer; seef-diagnostic; forms control; R232 interface; expanded/condensed print
B300	X		X		Band	FF	132	Sprocket	300 lpm	1-line buffer; forms control; condensed print.
Data Terminals and Communications DTC 302 RO		X	X		Wheel	FF	132/158	Friction (std) Tractor or Sprocket, opt.	45 cps	128 char. buffer
Decision Data 6540		X	X		Dot Matrix	9x7	132	Tractor	120 cps	Bidirectional printing 512 char. internal buffer

COMPANY AND MODEL	PRINT TYPE & METHOD: LINE	SERIAL	IMPACT	NON-IMPACT	PRINT TECHNIQUE	MATRIX SIZE	CHARS/ LINE	FORMS FEED	PRINT SPEED	REMARKS
Diablo Systems, Inc. Xerox Co. 1641	X	X			Wheel	FF	132	Tractor	45 cps	256-1,200 char buffer; current-loop interface; graphics
DI/AN Controls Series 30		X	X		Dot Matrix	7x7	132	Tractor	180 cps	68-2000 char buffer will print up to 12-part forms.
Digital Equipment Corp. LA180 DECprinter		X	X		Dot Matrix	7x7	132	Tractor	180 cps	256 char buffer in serial interface option
Epson America, Inc. Model 10	X		X		Belt	FF	80	Friction or PIN	150-200 lpm	80 char buffer
* Extel (Exchange Telegraph Co. Ltd.) M30/RO		X	X		Dot Matrix	5x7	72	—	10, 15, 30 cps	Choice of 8-level ASCII or 5-level CCITT #2
EXTEL AK		X	X		Dot Matrix	5x5 5x7	50/69/72/ 74/80	Friction	To 30 cps	8-level ASCII or 5-level Baudot
Facit-Addo, Inc. Facit 4540		X	X		Dot Matrix	9x9 7x9	155	Tractor	250 cps	256 char buffer
Florida Data Corp. PB-600		X	X		Dot Matrix	7x7 UC 8x7 LC	132	Sprocket	600 cps	896 char. buffer. Bidirectional printing, Serial interface option
General Electric Co. TermiNet 310/340 Series	X		X		Rotating Belt	FF	132	Tractor	90-340 lpm	Parallel or serial interfaces, buffered and unbuffered; Special interfaces on request
(GE Data Comm Prod) 1232	X	X			Belt	FF	132	Tractor	10/20/30/120 Cps	1,000 char buffer KSR;RO; Auto SR; Mag SR
Hewlett-Packard Co. HP 2631A		X	X		Dot Matrix	7x9	136 @ 10 CPI	Tractor	180 cps	Bidirectional printing Normal, expanded and compressed print modes.
Houston Instrument 8210 8230	X X			X X	Electrostatic Electrostatic	7x9 7x9	80 132	Friction Friction	2400 lpm 1400 lpm	One line buffer. Options include various codes and interfaces
Keinzle Apparate D3, D30 D300 D3000C, D3000	X	X X	X X X		Drum Dot Matrix Dot Matrix	FF 7x7, 7x9 7x7, 7x9	22 30 132, 158, 198	Friction PIN PIN	210 lpm 100, 156 cps 100, 156 cps	
MI^2 Corporation Design 2400		X	X		Dot Matrix	7x9 9x9	132/158/220	Tractor	220 cps	Options: programmable interface, selectable character sets, up to 8k buffer
NEC Information Systems, Inc. 5510		X	X		Thimble	FF	132/158	Tractor Friction PIN	55 cps	256 char. buffer. Bidirectional printing, Option: Bottom feed.
Philips Data Systems P 842 3324 3320 3310	X X X	X	X X X X		Dot Matrix Dot Matrix Dot Matrix 2 Mosaic Printheads	9x8 7x7 7x9 7x9	110 132 132 132	Friction/PEG Tractor Tractor Tractor	50 cps 400 lpm 200 lpm 70-80 lpm	KSR version available. Checks and of paper, parity, character validity

* Not to be confused with the American Company EXTEL whose products are marketed in Europe under the name "TRANSTEL".

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COMPANY AND MODEL	PRINT TYPE & METHOD: LINE	SERIAL	IMPACT	NON-IMPACT	PRINT TECHNIQUE	MATRIX SIZE	CHARS/ LINE	FORMS FEED	PRINT SPEED	REMARKS
Practical Automation										
DMPT 3		X	X		Dot Matrix	5x7	20	Friction	120 cps	1 line buffer. Options: Controller, power supply, cables
DMPT 6		X	X		Dot Matrix	5x7	80	Friction	120 cps	
Printronix, Inc. 300	X		X		Hammer Bank	9x7	132	Tractor	300 lpm	1 line buffer
Randal Data Systems RDS LA 180		X	X		Dot Matrix	7x7	132	Tractor	180 cps	512 char. buffer. Options: Additional 512 char. buffer, RS232 Interface, polling adaptor
SCI Systems, Inc.										
1100 Rotary		X		X	Electrosensitive	5x7	40/80/132	Friction	2200 cps	40 char. FIFO buffer.
2080		X	X		Dot Matrix	7x7, 9x9	80	Sprocket	140-200	320 char. buffer
2132		X	X		Dot Matrix	7x7, 9x9	132	Tractor	140-200	528 char. buffer
2184		X	X		Dot Matrix	7x7, 9x9	184	Tractor	140-200	736 char. buffer
Formed Character		X	X		Wheel	FF	0-132	Friction	45 cps	4-line buffer (2080, 2132, 2184; Bidirectional printing)
Scope Data, Inc. Comm 1200		X		X	Electrosensitive	7x9	80	Friction	500 cps	192 char. buffer; built-in self test. Serial or parallel interface
Siemens Corp.										
T-1000 RO		X	X		Wheel	FF	69/72	Friction	13.3 cps	Options: Paper tape, mag. tape.
PT 80		X	X		Dot Matrix	12x9	72/132	Tractor, Sprocket, Friction	90 cps	T-1000: Telex, private wire, polled network versions; PT80: TWX and polled net versions
PT 80 Ink Jet						12x9	72/132		300 cps	
Tally Corporation		X	X		Dot Matrix	7x7	212	Tractor	160 cps	1k (Standard) buffer 2k & 4k, opt. KSR, opt.
Teletype Corp.										
Model 43 RO		X	X		Dot Matrix	7x9	132; 80 opt.	Sprocket Friction opt.	30 cps	64-char. buffer
4010 – 3COO	X		X		Chain	FF	80 max	Friction	300 lpm	825 char. buffer
4010 – 3HOO	X		X		Chain	FF	80 max	Tractor	300 lpm	825 char. buffer
4010 – 3LOO	X		X		Chain	FF	132	Tractor	300 lpm	825 char. buffer
Texas Instruments										
743 RO		X		X	Thermal	5x7	80	Friction	30 cps	743 options: dc-current loop interface, answer-back, internal 300 baud originate modem
810 RO		X	X		Dot Matrix	9x7	132	Tractor	150 cps	Bidirectional printing. 256 char buffer
Tycom Systems Corp. KSR 38		X	X		Wheel	FF	156	Tractor, Sprocket, Friction	15 cps	128 char. buffer, RS-232 Interface optional
Versatec 1200A	X			X	Electrostatic	16x16	132	Friction	1000 lpm	Dual line buffer; plotting capability
Western Union Data Services EDT 1232		X	X				132		120 cps	Options include answer-back, 8 lines/in. printing, special fonts
Xerox Corporation 1710		X	X		Wheel	FF	132/158	Friction	30 cps	158 char. buffer. Options: Tractor or Sprocket forms feed; stand; acoustic coupler

FF = Fully Formed Characters

3.4.2 Future Trends

The future trends for receive-only printers are similar to those for teleprinters. The market for RO printers will be protected from encroachment by CRT's because of the need for permanent records. The market forces governing the need for low cost printers are: the growth of distributed processing which will spur the use of multiple lower speed, lower cost printers instead of a single expensive high-speed printer; the emergence of new telecommunications links which will increase communications; growth in small business systems which will require relatively low-cost, high quality, moderate speed printers. A special report on OEM printers is available in the February 20, 1979 issue of EDN which discusses the current and future technology developments in this area.

3.5 GRAPHICS DISPLAY TERMINALS

3.5.1 General Description and Specifications

Graphic terminals are special purpose CRT terminals designed to handle pictorial information. A wide range of available graphic displays provide high resolution at steadily decreasing prices. Applications involving graphic terminals include, animation, architecture, graphic art, data charting and plotting, computer aided design, cartography, simulation, pattern recognition, medical and several others.

The literature on computer graphics contains differing terminology and descriptions of the components of a graphic system. Basically there are four arrangements of displays: direct view storage tubes, directed beam or random scan, raster scan and scan converter. In addition the plasma panel has had limited use.

Direct view storage displays retain the visual image for some length of time so that it is not necessary to refresh to avoid flicker. The absence of refresh eliminates the refresh memory. The resultant system is usually available at a lower price than others. The disadvantages are low luminance and contrast, and the need to rewrite the entire picture if an element is changed.

Random scanning technique moves the CRT beam simultaneously in a random X-Y direction. The beam is moved directly to the X-Y coordinate at which the graphics element is to be displayed and turned on - then it is deflected to trace the desired graphics element and turned off. Random scanning offers high resolution, but is limited in color capability and flicker-free information content.

A raster scan screen is usually a grid of dots. A raster line is represented by illuminating the dots located along the path of the line. Raster scan graphics usually operate at a rate similar to the home television's 525 line system. Raster scanning offers excellent color presentation and high flicker-free information content but is limited in resolution.

Scan conversion is one form of refresh memory used in some terminals. Their advantage is higher resolution, ability to selectively write or erase any portion of the image, and magnifying part of the image in hardware without host computer intervention. The major components of a graphics display system are the host computer, a display generator, graphics display device and graphics input devices. The host computer serves as the source of graphical commands and provides the display generator with coded inputs. The display generator then creates bit-level commands to the graphics-output devices which present graphics outputs in shades of gray or in color. A variety of graphics-input devices are often interfaced to the host computer or the display generator.

The display generator consists of a display processor, a display controller, refresh memory and a video driver. Processing power may reside entirely in a single user computer or it may be time shared out of a large control processor. The display processor is a component of the display generator which in some applications provides part of this processing capability. The four tasks to be accomplished are: controlling the display, accepting input commands, managing a data base and computing display relationships. The vector and raster scan displays have to be refreshed. The display controller provides a hardware memory of what is currently on the screen and a means of translating the memory contents into signals that control the deflection of the electron beam. Most terminals come with the display control function implemented in special purpose hardware. Both polling and interrupt procedures are employed to acquire input commands from input devices. In some applications such as displaying map data, where a substantial amount of information is needed, the graphics software would require interfacing with data base systems. Examples of computing display relationships are: translating the picture from one screen position to another (panning), scaling the picture up (zooming) and rotating the picture through an angle.

The common input devices are the keyboard, pointing device and tablet. In addition to alphanumeric information the keyboard has keys for moving a cursor on the screen. The pointing device serves to point to something on the display before acting on it according to a command. The joystick, tracker ball, or rolling 'mouse' enable the user to position the screen cursor independently of the keyboard. The tablet permits the user to create on the screen lines drawn on the tablet.

The graphic display screens usually provide between 40 and 200 resolvable points (picture elements) per inch. The approximate vector width varies from .025 inches to .005 inches. At 40 points per inch on a 13 inch screen with character size of 10x7 points approximately 40 lines of 70 characters of text are possible. With 200 points per inch with a finer character size of 16x9 points, 120 lines of 200 characters per line are possible.

Table 3.5-1 lists some representative graphic terminal models and their specifications and costs. Table 3.5-2 is a list of some of the manufacturers of graphic systems.

3.5.2 Future Trends in Graphic Terminals.

Application areas for computer-aided graphic display systems have been increasing since their introduction, due to the vast quantities and complex inter-relations of information which can be organized and manipulated in a visual format. On the hardware side costs are coming down and capability is going up. With memory becoming less expensive higher resolution displays become feasible. On the software side many standardized display packages are on the market. Some suppliers provide general purpose programs and special languages that allow their terminals to be easily applied to specific applications. However, there is presently little evident effort from manufacturers to standardize software or languages. Support of graphic standards and increased emphasis on support of system configuration will become evident.

Table 3.5-1

Representative Graphic Terminal Models and Specifications

Model	Display type and area	Alphanumeric mode	Graphics mode	Some options available	Cost
Tektronix 4012/13	Direct view bistable storage CRT. Display area 8 inches wide by 6 inches high.	94 characters on 7x9 dot matrix (ASCII). Model 7013 comes with 94 character APL set.	Vectors only. Vector drawing time 2.6 ms 1024x1024 addressable points, 1024x780 viewable points	Basic data communications interface is EIARS 232 A or C compatible, full duplex only. Option 1 provides optional data communications interface, includes echo-plex, full and half duplex and independent transmit and receive rates from 110 to 9600 bits/sec. TTY port options include six teletype port interfaces for use with mini computers.	4012: $6495 4013: $6995 Option 1: $1425
Tektronix 4014-1	Direct view bistable storage CRT. Display area 15 inches wide by 11 inches high	Full ASCII character set (94 printing characters). Model 4015-1 includes APL character set. Four program selectable character formats: 74 characters/line with 35 lines per display. 81 characters/line with 38 lines per display.	Vector drawing time 5000 inches per second. 1024x1024 addressable points 1024x780 viewable points	Option 34 enhanced graphics module: 4096x4096 addressable points, 4096x3120 viewable points; 5 vector formats; point plot mode with program control of plotted point size from .01 to .05 inch. Incremental plot mode relative addressing 1 of 8 directions one step at a time. Option 40 programmable keyboard capability to save graphic displays, picture segments, symbols and alphanumeric in 3K standard local memory.	4014-1: $12,195 4015-1: $13,245 Option 34: $795 Option 40: $1695 Option 41: $150 Option 26: $600 Option 27: $1200 Options 41,26 and 27 require Option 40

Table 3.5-1 (cont'd)

Representative Graphic Terminal Models and Specifications

Model	Display type and area	Alphanumeric mode	Graphics mode	Some options available	Cost
Tektronix 4014-1 (cont'd)		121 characters/ line with 58 lines per display 133 characters/ line with 64 lines per display		Option 41 expanded symbol and character package to add alternate stroke drawn character set, local rotation by 1° increments, local scaling of graphics upwards and downwards, local generation of circles and circular arcs and local design of symbols and character sets. Options 26 and 27 provide 16K or 32K additional memory with Option 40.	
Tektronix 4016-1	Direct view bistable storage CRT. Display over 18 inches wide by 13.5 inches high	Full ASCII (94 characters) character set. Standard character formats: 74 characters/ line by 35 lines. 81 characters/ line by 38 lines. 133 characters/ line by 64 lines. 179 characters/ line by 86 lines. Four other optional formats available.	Vector drawing time is 8000 inches per sec. 4096x1096 addressable points. 4096x3120 viewable points. 5 vector formats including straight,dotted and dashed lines. Special point plot mode with program control of point size. Incremental plot mode relative addressing 1 of 8 directions one step at a time.	Option 40,41,26 and 27 as described with model 4014-1. Option 5 provides peripheral control interface	4016-1: $19,500 Option 5: $750 requires options 40 and 41 and 26 or 27.

Table 3.5-1 (cont'd)

Rapresentative Graphic Terminal Models and Specifications

Model	Display type and area	Alphanumeric mode	Graphics mode	Some options available	Cost
Tektronix 4020 series (4025 & 4027)	Video monitor; 12 in.diagonal screen; P-39 screen phosphor. Standard 525 line scan.	Standard upper and lower case ASCII. Optional ruling or math characters. 80 characters/ line, 34 lines per display.	Graphics memory 48K bytes standard with Model 4027. Dot matrix display; each graphics cell has 14 rows of 8 dots each. Line types: solid lines, dashed lines, patterned lines, single points, and erase vectors which erase current vectors. Model 4027 comes with a 64 color palette with up to 8 colors displayed simultaneously.	Options 23-29 increase graphics memory capability from 4K bytes to 192K bytes. Optional interface with host computer and peripheral devices. Option 10: polling interface Option 11: polling controller.	4025: $3595 4027: $8695 Options 23-29: $550-$9000 Option 10: $250 Option 11: $2000

Table 3.5-1 (cont'd)

Representative Graphic Terminal Models and Specifications

Model	Display type and area	Alphanumeric mode	Graphics mode	Some options available	Cost
Tektronix 4051	Direct view storage CRT. Display size 8 inches wide by 6 inches high.	Full ASCII character set. Also includes Scandinavian, German, General European and Spanish fonts. 72 characters/line, 35 lines.	Graphic resolution 1024x780 points. Comes with a central processing unit which offers local computing and calculating power, with a standard 8K byte workspace and basic vocabulary	Workspace memory expendable to 32K bytes. Optional Data Communications Interface.	$5995
Tektronix 4663 Digital Plotter	X axis 22.4" max. Y axis 17" max. Microprocessor controlled stepping motors	95 ASCII, 15x7 matrix, 7 special fonts. 110-9600 bps band rate.	Resolution .001" Repeatability $\pm$.0025" Point plotting rate: 10 pts.per sec.max. Max plotting speed 16-22 ips.	Interface options and performance options. Option 31: Circular interpolation and programmable macros. Option 32: Math character set and down loadable character set Option 36: paper advance.	$9495 Option 31: $525 Option 32: $450 Option 36: $700
Megatek 5000	Full refresh. P40,P39 phosphors standard, other phosphor available. 21" diagonal monitor standard, special sizes available 13"x14" viewable area. Spot size 15 mil standard, 10 mil optional	Upper,lower case ASCII is standard. 8 character sizes, 4 angles of rotation.	Nova 3 based interactive refresh system couples with a MG552 microprocessor based graphics display unit. 12 bit (4096x4096) screen resolution. Vector generator for end point matching and constant intensity control. End matching .005" typical	Multiple monitors, keyboard interface, Joystick interface, Hardware character generator. User definable characters. 16 bit minicomputer expandable up to 128K words.	

Table 3.5-1 (cont'd)

Representative Graphic Terminal Models and Specifications

Model	Display type and area	Alphanumeric mode	Graphics mode	Some options available	Cost
Megatek 5000 (cont'd)			End closure: .005" typical. 16 levels of intensity. Selective erase translation, rotation,zoom and scale area standard. Four vector types: absolute,relative (long and short),incremental Model 5014 adds communication capability to emulate Tektronix 4014 terminal.		
Megatek 7000	Full refresh P40 P39 phosphors standard. 21" diagonal monitor with 13"x14" viewable area. Spot size 15 mil standard, 10 mil optional	Upper lower case ASCII, 8 character sizes four rotations.	Self contained refresh memory: Microprocessor based with 32 bit graphics word; 12 bit resolution standard; 16 levels of vector intensity. May be used in conjunction with most current 16 and 32 bit minicomputers. Four vector types: absolute,relative (long and short), incremental. Selective erase,hardware blink,hardware dashed lines.	Hardware options include rotation, scaling,clip. RAM memory expansion to 32K words, 32 bit memory in 2K word blocks	Graphic display unit $18,000 with Data General NOVA or DEC PDP-11 direct memory access interface. Hardware clip module $3,000. Hardware clip. rotate,scale, translate module $6,000. Additional 64K byte RAM memory $6,000. 21" monitor with 15 mil spot size $5,400

Table 3.5-1 (cont'd)

Representative Graphic Terminal Models and Specifications

Model	Display type and area	Alphanumeric mode	Graphics mode	Some options available	Cost
Princeton 8500M	20" diagonal, 1029 line raster. Solid state beam addressed image memory	Full ASCII Three hardware text sizes: 80 characters/ line, 34 lines 120 characters/ line, 51 lines 60 characters/ line, 26 lines 0°-360° rotation. Programmable text size mode.	Graphics addressable matrix 8192x8192; visible matrix 4096x 3072. Drawing speed 5500 in/sec. Absolute and relative vector formats. 32 level gray scale. Dot, dash, dot-dash texturing. Point plot mode, plot scan mode, hardware generated conics, full screen cursor, windowing and scaling, user designed symbols. 130 discernible characters/line, 55 lines. Full screen erase in 250 ms selective erase.	Cassette drive, floppy disk, APL keyboard, additional image memories, additional character RAM and software support packages are included as options.	$18,900 without options.
Hewlett Packard Model 2647A	Screen size: 5"x10". Screen capacity: 24 lines x 80 columns for alphanumeric and 720 dots x360 rows for graphics. Non-interlacing raster scan,	128 upper and lower case ASCII character set 75 lines x 80 characters alphanumeric memory	White on black, black on white display modes are standard. Graphics memory 720 dots x 360 rows of displayable points 16K bytes Basic workspace. Vector drawing time 7 ms half screen; 10 ms full screen. Shared peripheral support limited to a maximum of 4 devices	Optional display enhancements; half bright, underline and blinking, and three 128 additional character sets. 64 character math symbols set and large character set.	$8,300 Display enhancements $250 Math symbol set $100

Table 3.5-1 (cont'd)

Representative Graphic Terminal Models and Specifications

Model	Display type and area	Alphanumeric mode	Graphics mode	Some options available	Cost
Hewlett Packard Model 2647A (cont'd)	7x9 for alphanumeric character generation, 9x15 dot character cell for graphics. .097"x.125" alphanumeric character size.				
Hewlett Packard Model 2648A	Raster scan technology	Full interactive alphanumerics capability	Graphics memory with 720 by 360 displayable points. Hardware zoom and pan, rubberband line, rectangular area shading		$5,500
Hewlett Packard 2631G graphics printer	Serial printer with the ability to print raster data format graphics 180 cps instantaneous print speed. 7 column by 9 rows dot matrix. Impact printing allows multi-part forms handling.	128 ASCII character set.	72x72 dots per inch graphics resolution. Dual input buffers allow data storage while printing.	Additional character sets including European character sets and math character sets.	

Table 3.5-1 (cont'd)

Representative Graphic Terminal Models and Specifications

Model	Display type and area	Alphanumeric mode	Graphics mode	Some options available	Cost
Sanders Graphic 7	Viewing area: Model 530 has 12x16 inches Model 565 has 20 inches circular. Spot size .02" P31 phosphor others available.	192 ASCII character: 96 standard characters and 96 customer defined options. Can be rotated 90° counterclockwise. Features four character sizes, two speeds and adaptive timing.	Addressable locations 2048x2048, viewing locations 1024x1024. Four line type, two programmable speeds and adaptive timing. Microprocessor controlled with 4K, 16 bit words of ROM and 8K to 24K words of RAM. Basic system comprises a terminal controller, CRT display, input devices.	Conic generator, coordinate convertor. Data entry devices include, keyboard, photopen, joystick.	Terminal controller $23,900. Serial interface: $1200 21" diagonal monitor $6200 Keyboard $1500 8K word memory $2500
Ramtek 6200A	Non interlaced raster scan 13" CRT diagonal, visible raster: 10"x 7.5" 51 pixels/in x 34 pixels/in.	96 ASCII characters. 72 or 80 columns by 25 line format 7x10 character cell 5x7 character matrix	Microprocessor controlled 512x256 displayable pixels Vectorspeed: 20 μs/pixel,horiz 66 μs/pixel,vert 112 μs/pixel,angle Vector type: solid Primary color table - 8 colors Display modes:reverse background, blink and underline.	Patterned vectors Blink mode 35 of 69 color shades.	Colorgraphic computer terminal: $9,950. Scratchpad memory extension: $750. Special graphics color PROM: $500. Graphic blink overlay: $300. Patterned vectors/fill firmware: $500.

Table 3.5-1 (cont'd)

Representative Graphic Terminal Models and Specifications

Model	Display type and area	Alphanumeric mode	Graphics mode	Some options available	Cost
Ramtek 6310	Non interlaced raster scan, 19" CRT diagonal, visible 15"x 11.2"	96 displayable ASCII characters. 80 columns x 40 lines format 7x9 character cell 10x15 character matrix	Z-80 processor for terminal control, 32K bytes of ROM and 16K bytes of RAM standard. Displayable pixel matrix 800x600. Addressable pixel memory 1024x1024 Vector speed: 40 µs/pixel in any direction. Vector types: solid line,dash,dot,dot-dash or user defined. Hardware color zoom pan. User programmable 8 colors from a set of 64. Display modes; blink, reverse video and underline.	Processor memory extension adds 16K bytes of RAM. RAM expansion card allows user to add RAM in 32K byte partitions. ROM expansion card allows 64K bytes to be added to the memory map. Graphic memory allows a 4th memory plane of 1024x 1024	
Ramtek 6110	Non interlaced raster scan, 13" diagonal CRT. 10"x7.5" visual 262 line/60 Hz repeat field or 312 line/ 50 Hz repeat field video format.	96 displayable standard ASCII characters 5x7 character matrix 8x10 character cell	Z-80 processor for terminal control with 32K bytes of ROM and 16K bytes of RAM standard. Displayable pixels 320x240 Vector speed: 120 µs/pixel any direction	Processor memory extension (16K) RAM expansion card ROM expansion card	

Table 3.5-1 (cont'd)

Representative Graphic Terminal Models and Specifications

Model	Display type and area	Alphanumeric mode	Graphics mode	Some options available	Cost
Ramtek 6110 (cont'd)			Vector type: solid line, patterned or user defined. Primary colors - 8 Display modes: blink, reverse video, underline.		
Linidata System 3400	Refreshed raster scan display system,either 30 Hz interlaced or 60 Hz non-interlaced available	Standard 5x7 gives 80 characters per line by 64 lines for 640x512 resolution	Dual processors control CRT refresh and graphics and image manipulation. Picture memory: upto 640x512 pixels for 1 to 16 bits per pixel; upto 1280x1024 pixels for 1 to 4 bits per pixel. Pixel update times: random or sequential update at 750 µs/pixel; randome or sequential readback at 1 µs/pixel. Vector drawing time: set up is 10 µs; drawing is 2 µs/pixel.	Special character options. Upto 256 levels of gray can be displayed simultaneously selected from upto 4096. Upto 1024 colors can be displayed simultaneously selected from $2^{24}-1$ combinations. Hardware implemented linear interpolation on a 2x or 4x zoom. Zoom, scrolling and blinking are available as options.	Prices start at $4,810

Table 3.5-1 (cont'd)

Representative Graphic Terminal Models and Specifications

Model	Display type and area	Alphanumeric mode	Graphics mode	Some options available	Cost
Linidata System Model 200-D	Raster scan display system, 60 Hz vertical scan rate, 15.75 KHz horizontal. Scan rate can also be set to 25, 30 or 50 Hz.	5x7 dot matrix: 512x512 with 64 lines at 85 characters; 256x256 with 32 lines at 42 characters. Standard 64 characters ASCII upper case font supplied.	Video graphics and imaging display processor for the NOVA and ECLIPSE series computers: 16 gray levels from 256 level look-up table. 16 preassigned colors to a standard RGB color monitor. Upto 32K bytes of MOS image memory. Standard memory configuration 512x512 pixels x 1 bit, or 512x480 pixels x 1 bit for B&W monochrome; 256x256x4 bits or 256x240x4 bits for 16 level gray or color. Random access, single pixel update at 800 μs/ monochrome pixel, 2 μs/ gray scale pixel.	Color look-up table; upto 16 out of 4096 colors may appear at one time.	Prices start at $2,900.

Table 3.5-2

List of Manufacturers of Graphic Terminals

Comtal Corp.
169 N. Halstead
Pasadena, CA 91107
(213) 793-2134

DeAnza Systems Incorporated
3444 De La Cruz Blvd.
Santa Clara, CA 95050
(408) 988-2656

Genisco Technology Corporation
Computers Division
17805-D Sky Park Circle Drive
Irvine, CA 92714
(714) 556-4916

Hewlett Packard
1501 Page Mill Road
Palo Alto, CA 94304
(408) 249-7000 (Sales Office)

Linidata Corporation
215 Middlesex Turnpike
Burlington, MA 01803
(617) 273-2700

Megatek Graphic Systems
3931 Sorrento Valley Blvd.
San Diego, CA 92121
(714) 455-5590

Princeton Electronic Products, Inc.
P.O. Box 101
North Brunswick, NJ 08902
(201) 297-4448

Ramtek
585 North Mary Avenue
Sunnyvale, CA 94086
(408) 735-8400

Sanders Associates, Inc.
Daniel Webster Highway, South
Nashua, NH 03061
(603) 885-5280

Tektronix, Inc.
3233-2 Scott Blvd.
Santa Clara, CA 95051
(408) 243-9620

Vector General
Sandy Plaza Office Bldg.
599 North Mathilda Ave.
Sunnyvale, CA 94086
(408) 736-6141

3.6 DATA MODEM EQUIPMENTS

3.6.1 General Description and Specifications.

Data modems are the modulators and demodulators used in data communications. At the transmitting end, the modem converts binary digits (1's and 0's), or pulses, into a continuously varying signal such that the signal can be transmitted through some communications channel; at the receiving end, the modem converts the received signal back into binary digits, or pulses. These equipments provide the connection among all data systems and computer units, and make the rapid growth of data communications and wide applications of computers possible in recent years. This section is to give a brief description of the types, characteristics, and applications of these equipments.

3.6.1.1 Modulation

The three basic types of modulation are amplitude modulation (AM), frequency modulation (FM), and phase modulation (PM). In data communications these types are usually referred to as amplitude shift keying (ASK), frequency shift keying (FSK), and phase shift keying (PSK) because only a limited number (usually 2, 4 or 8) of amplitude, frequency or phase values are to be used. In PSK type, a special scheme called differential phase shift keying (DPSK) is sometimes used, in which it is the phase difference between two successive symbols instead of the absolute phase that represents the binary digits. Various combinations of these basic modulations are also used, for example, the combination of 4 phases and 2 amplitudes can give 8 different signals, which provide one 3-bit symbol. The modulation schemes and the values of amplitudes, frequencies, and phases of the signals, determine the error characteristics of the modem, i.e., which value of signal-to-noise ratio gives which value of error rate. This is why the modulation scheme determines the performance of the modems in the first place.

3.6.1.2 Synchronization

Most modems with speeds up through about 1200 bits per second (bps) use the asynchronous mode, in which the data bits of each character are preceded and followed by special start and stop bit sequences. These special patterns of start/stop pulses separate the characters and assure that the receiving terminal knows when a character is arriving and when it ends. On the other hand, the modems with speeds of about 2000 bps or higher usually use the synchronous mode, in which a constant rate clock usually in the modem itself is used to determine the exact instant at which characters start and stop in both transmitting and receiving end. Because synchronous mode eliminates the need for the special start/stop pattern sequences, it is more efficient in utilizing a given amount of available line capacity than the asynchronous mode. But this efficiency is not necessary for lower speed modems. However, the synchronous mode requires more complex equipment in order to synchronize the clocks at both ends of the communications link.

3.6.1.3 Line Requirements and Digital Interface

When a modem is used to link an arbitrary terminal or computer to a data communication network, the connection conditions of both sides of the modem are important. The condition for the modem to connect to the network line is referred to as the line requirement here, and the condition for the modem to interface with the arbitrary terminal or computer is referred to as the digital interface. The most commonly accepted line requirement is that of the Direct Distance Dialing (DDD) network, including the control functions, switching facilities and signaling schemes of the DDD network. For example, the need to propagate ringing signals, busy signals, address digits, etc. in the DDD network necessitates that the modem must avoid putting energy into certain portions of the line bandwidth; otherwise these signals could be mistakenly interpreted for the control functions. For the digital interface, the standards developed by the Electronics Association (EIA) are most commonly accepted in the United States, and those developed by the CCITT are most commonly accepted in the other countries of the world. These standards specify the way in which each pin is connected and the respective signals and levels on each pin. Generally speaking, the EIA and CCITT standards are functionally similar, but they are not actually identical for all applications.

Proper timing diagrams and other information about these connection conditions are usually provided by the vendors.

3.6.1.4 Full-Duplex Operation

Today almost all data modems have full-duplex operation capability over the telephone line for most data rates. The typical voice-band telephone line has a response curve from about 300 Hz to about 3400 Hz. Full-duplex operation usually makes use of this band by dividing it into two parts, a lower half band from about 500 Hz to about 1800 Hz, and a higher half band from about 2000 Hz to about 3400 Hz. The signals in the forward and reverse directions are then put in these two different parts of the voice-band such that two-way transmission can be performed simultaneously without significant interference. Some of the modems also use half-duplex operation or simplex operation capabilities, which are usually clearly specified by the vendors.

3.6.1.5 Specifications and Costs of Data Modems.

The most important specification of a data modem for public service users is the data rate. Today available modems have data rates varying from about 75 bps to as high as 230 kbps. Even higher rates, such as 1.554 Mbps, also exist. This data rate is directly related to the communication throughput and is sometimes a dominating parameter which determines the prices of the modems. For example, the prices of synchronous modems with data rate less than 4800 bps is in general about $0.3 - $0.6 per bps, i.e., a 4800 bps modem usually costs $1440 - $2880.

Other important specifications include modulation, synchronization, line requirement, digital interface, duplex operation, etc., which have been explained in the above sections. Some typical models of data modems produced by typical vendors with their specifications and costs are listed in Table 3.6-1, in which series of models with similar performance are combined as a single row to reduce the table size. The addresses and phone numbers of the vendors listed in Table 3.6-1 and other vendors are listed in Table 3.6-2 as a reference.

Table 3.6-1

Specifications for Typical Data Modem Models

Company	Model	Data Rate	Operation	Synchronization	Modulation	Line Requirement	Digital Interface	Cost
Codex	LSI 24/24	1600-3200 bps	Full or half duplex	Synchronous	QAM	DDD Networks	EIA RS-232-C CCITT V.24	$476 - 590
	Other LSI Series	2400,4800, 7200, 9600 bps	"	"	QAM	3002 telephone line CCITT M1020	EIA RS-232-C CCITT V.24 MIL-STD-188 optional	
	5000 Series	300-1200 bps 2000,2400 bps	Full duplex	Asynchronous Synchronous	FSK	DDD Networks 3002 telephone line	EIA RS-252-C	$345 - 625
Universal Data Systems	UDS 12.12	300-1200 bps 1200 bps	Full duplex	Asynchronous Synchronous	DPSK	"	EIA RS-232-C CCITT V.24	$576 - 600
	UDS 103/113 Series	0-300 bps	Full duplex	Asynchronous	FSK	"	"	$275 - 395
	UDS 201 series	2000-2400 bps	Full or half duplex	Synchronous	DPSK	DDD Networks	"	$785 - 885
	UDS 202 Series	0-1200 bps 0-1800 bps	Full or half duplex Full or half duplex	Asynchronous or Synchronous	FSK	DDD Networks 3002 telephone line	"	$395 - 575

Company	Model	Data Rate	Operation	Synchronization	Modulation	Line Requirement	Digital Interface	Cost
-	UDS 208 Series	4800 bps	Full or half duplex	Synchronous	8 PSK	DDD Networks	"	$2350 - 2875
American Modem Corp.	740 Series	150~19200 bps	Full or half duplex	Synchronous	BPSK	BBC Networks CATV "	EIA RS-232-C CCITT V.24	$775
	1250 Series	1.2~ 230.4 kbps	Full or half duplex or simplex	"	QASK	DDD Networks	EIA RS-232.C Bell 303,V35	$3200
	1440 Series	1.2~250 kbps	Full or half duplex	"	BPSK	"	"	$4000
	1463 Series	1.2~128 kbps	"		QPSK	"	"	$2800 TX $5000 RCV
GTE Lenkurt	25C	75-600 bps	Full or half duplex or simplex	Asynchronous	FSK	DDD Networks	EIA RS-232 C CCITT V.24	$340-385
	26C 40.8 kbps	20.4, 40.8 kbps	Full or half duplex or simplex	Synchronous	FSK	"	"	$1640-2020
	261 A	2400 bps	Full or half duplex	"	FSK	3002 telephone line	"	$825

Company	Model	Data Rate	Operation	Synchronization	Modulation	Line Requirement	Digital Interface	Cost
Com Data Corp.	150 Series	300 bps	Full or half duplex	Asynchronous	FSK	DDD Networks	EIA RS-232	$130-147
	302 Series	"	"	"	"	"	"	$200-250
	212 Series	1200 bps	Full duplex	Asynchronous Synchronous	"	3002 telephone line	"	$895
Bell System	300/1200	0~300 bps 1200 bps Dual-speeds	Full duplex	Asynchronous Synchronous	FSK	DDD Networks	EIA RS-232 C	Sold only to Bell System.
Rixon, Inc.	T 108 Series	0~300 bps	Full or half duplex	Asynchronous	"	DDD Networks or 3002 telephone line	EIA RS-wew C	$250-320
	T 113 C Series	"	Full duplex	"	"	DDD Networks	"	$370-400
	T 212 A Series	0~300 bps 1200 bps Dual-speeds	"	"	FSK or PSK	DDD Networks or 3002 telephone line	"	$765-855
	T202 T Series	0 1800 bps	Full or half duplex	"	FSK	"	"	$370-560

Company	Model	Data Rate	Operation	Synchronization	Modulation	Line Requirement	Digital Interface	Cost
	T 208 Series	4800 bps	Full or half duplex	Synchronous	PSK	"	"	$2685-2810
Gandalf	LDS 120D	up to 9600 bps	Full or half duplex	Asynchronous	PSK	"	"	$300
	LDS 309D	up to 19200 bps	"	Synchronous	"	"	"	$685
Hubbell Pulsecom Division	4010 Series	up to 300 bps	"	Asynchronous	FSK	"	EIA RS-232	$190
	4012 Series	"	"	"	"	"	"	$190

Table 3.6-2

Data Modem Vendors

Company	Address	Phone No.
Codex Corp.	15 Riverdale Ave., P.O. Box 160, Newton, MA 02195	617/969-0600
Universal Data Systems, Inc.	4900 Bradford Drive, Huntsville, Alabama 35805	205/837-8100
American Modem Corp.	160 Wilbur Place, Bohemia, NY 11716	516/567-7887
GTE Lenkurt	1105 Old County Rd, San Carlos, CA 94070	415/595-3000
Com Data Corp.	8115 Monticello, Skokie, Ill. 60076	312/677-3900
Penril Corp.	5520 Randolph Rd, Rockville, MD 20852	301/881-8151
Avanti Communications Corp.	Box 205, Broadway Station, Newport, RI 02840	401/849-4660
Gandalf Data Inc.	1019 S. Noel, Wheeling, Ill 60090	312/541-6060
General Data Comm., Inc.	131 Danbury Road, Wilton, CT 06897	203/762-0711
Tele-Dynamics	525 Virginia Dr., Fort Washington, PA 19034	215/643-3900
Harvey Hubbel, Inc.	Pulsecom Division, 5714 Columbia Pike, Falls Church, VA 22041	703/998-4300
Rixon, Inc.	2120 Industrial Parkway, Silver Spring, MD 20904	301/622-2121

3.6.2 Future Trends

The developments in manufacturing data modem equipments are currently concentrating on making use of new technologies to improve the equipment performance. The new technologies to be used include high speed microprocessors, improved adaptive equalizers, low-cost error detection and correction coding techniques, etc. The improved performances desired include higher data rates, lower error probabilities, more automatic operation, lower power consumption, smaller size, lighter weights, decreased prices, etc.

An important potential area in future developments is the increasing interface compatibility with the new protocols and new formats of advanced data transmission networks. Many advanced techniques have been proposed and analyzed to improve network performances such as increasing capacity and throughput, decreasing delay and cost, etc. Typical examples include slotted and unslotted schemes, reserved and unreserved schemes, 1-persistent, p-persistent, non-persistent schemes, Carrier Sense Multiple Access (CSMA), etc. On the other hand, the communication channel media used in the networks are also continuously being up-dated. For example, high-capacity, low-cost optical fibers are probably going to take the place of telephone lines in the future, and high gain satellite technologies will make the low-cost, simple-operation, small earth terminals very popular in the future. The future modems will have to be compatibly interfaced with these advanced data networks.

Another important potential area of future developments for data modems is the implementation of the "modern" cryptography techniques to improve the security of the data transmission. Until recently, cryptography has been of interest primarily to the military and diplomatic communities only. However, today both private individuals and commercial organizations find increasing importance in the security of their data transmission due to many factors which are changing the world. A few apparent factors include: the trend that most business is to be conducted by telecommunication media instead of the conventional personal contact and written correspondence; the trend that telecommunication is to become completely digital some time in the future and the fact that digital data are more vulnerable in new technologies such as high-speed microprocessors and low-cost microcomputers which are very helpful in both eavesdropping, interpreting secret data as well as building security cryptosystems to protect the data, etc. Substantial efforts have been made in this area and many fascinating techniques have been suggested to build low-cost, high-security cryptosystems. Typical examples include different schemes of public key systems, different schemes of digital signatures, etc. Clearly the implementation of these cryptographic techniques will be an important future trend in the development of data modems.

4. FULL MOTION AND PROCESSED VIDEO EQUIPMENT.

The subject section is full motion video equipment. Video terminus equipment of interest falls into one of four categories:

Cameras
Video Tape Recorders
Video Monitors
Television Projectors

These same categories will be covered also in the next phase, which covers processed video. The actual terminus equipment considered here is that which acts as the transducer of visual images into electronic signals and back again into visual images for display. A great deal of ancillary equipment is used in the production and display of video signals. Most of this additional equipment is also available from the various suppliers discussed in this report. Examples of equipment not covered here are Telecine equipment, i.e., the projectors that are used to convert regular movie film into video tape, various mixers and faders used to create the special effects seen on commercial TV, synchronizers, sync generators, and multiplexers.

4.1 VIDEO CAMERAS

4.1.1 General Description and Specifications

The video camera converts reflected light from a scene into electronic signals by forming an image thru an optical system, converting this image to a voltage in an image pickup tube, and amplifying the signal for use in the following parts of the system. Deflection circuits in the camera scan the image in a programmed fashion.

The camera optical system can be equipped with special devices such as zoom lenses and irises for light control. In a color TV system, color sensitive mirrors and filters split the light into three primary color components. The passband of each color channel is carefully controlled to give the prescribed response. The output of each color channel is amplified and then the three signals are combined in an encoder for processing into a composite video signal which is transmitted. The TV receiver decodes this complex signal and recombines the three color channels in a matrix which restores the level and phase of each color component in the original picture.

The camera head itself contains the optical system, the color filters and mirrors, the image pickup tubes (one for each primary color), plus the amplifiers and deflection (scanning) circuits. A unit which is usually physically separated from the camera head contains the encoders and signal adders and output amplifiers. This separate unit, known as the camera control unit, generates the various synchronizing and control signals for the camera head and also inserts these synchronizing signals onto the composite video signal before transmission. The camera control unit often contains a picture monitor scope and a waveform monitor scope. A picture monitor scope is also placed in the camera head in such a way that the cameraman can use it for a viewfinder.

TV cameras are available as large, tripod-mounted studio cameras as well as small, shoulder-mounted portable models. Specifications for cameras, like most video equipment, are compliant to one or more of several national or international standards. Scan standards are either EIA 525 line-60 fields (U.S.) or CCIR 625 line-50 fields (Europe).[1] The number of lines in the specification simply denotes the number of scanning lines from top to bottom on one picture. The number of fields is controlled by the power line frequency, where a field is defined as a complete set of scanning lines from top to bottom of the picture. The scanning lines, however, are spaced so that the lines from two consecutive fields are interlaced, thus requiring two fields to make one complete picture, or frame. The frame rate is thus 30 or 25 frames per second in the EIA or CCIR systems, respectively. The picture is thus actually refreshed at twice the frame rate and this feature effectively eliminates any flicker that might be noticeable from the display if it were refreshed only 25 to 30 times per second.

Color standards are typed by NTSC, PAL-B, PAL-M, or SECAM.[2] These standards control the encoding and decoding of the color components, their relative amplitudes and phases, and the manner in which they are separated and recombined. Other specifications that are standardized for all cameras and video equipment have to do with composite output pulse voltages, synchronizing pulse heights, timing, and waveform, and interface impedances. Different brands of cameras may vary in the quality, accuracy, and resolution of the optical system, sensitivity of the image tubes plus various controls and environmental and mechanical specs. Signal-to-noise ratio is measured according to NTSC or PAL procedures. A set of typical specifications follow in Table 4.1-1, and these specs are followed by a tabulation of suppliers and their various models.

(1) EIA = Electronic Industries Association.

CCIR = French terminology - International Consultative Committee on Radio.

(2) NTSC = National Television Systems Committee (U.S.)

PAL = Phase Alteration Line (British)

SECAM = Sequential Couleur A Memoire (French-Russian)

Table 4.1-1

Typical TV Camera Specifications

Scanning Standards	EIA 525 lines, 60 fields CCIR 625 lines, 50 fields
Power Requirements	120 VAC, 60Hz, approx 160 watts
Pick-up Tubes	Red: Amperex XQ1074 Blue: Amperex XQ1071B Green:Amperex XQ1070G
Synchronization	Internal sync: EIA RS-170 External sync: Horiz. Drive 2-8Vpp,neg. Vert. Drive 2-8Vpp,neg. Subcarrier 1.5-4Vpp.
Outputs	Program Video (Composite x2)1Vpp across 75 ohm. Chroma Key (non-composite)0.7Vpp across 75 ohm. Monitor Video 0.7Vpp across 75 ohm
Video Frequency Response	Less than 4MHz: $\pm$ 0.5 dB at 6MHz : + 1 dB, -2dB
Horizontal Resolution	Center: more than 500 lines Corner: more than 400 lines

Picture Geometry	All zones: 1.0%
Illumination(Sensitivity)	Minimum incident light for full output with £/2.0 lens: 10 foot-candles Incident light for rated Signal/Noise: 85 fc at £/2.8
Signal-to-Noise Ratio	(300 nA, green signal current, 1.0 gamma, 4.2 MHz bandwidth; masking, aperture, and chroma off): 48 dB
Registration Accuracy	Zone 1 (Circle = .8V) 0.15% Zone 2 (Circle = 1.0H)0.3 %
Optical System	Color Separation: Sealed relay optics Correction filters: Lens accessory Depolarization : Retardation plate at optical input.
Aperture Correction	Horizontal: 10 dB boost at 3 MHz
Operating Environment	Temperature: -20°C to +40°C Humidity 0-95% RH Altitude 0-10000 ft.

Also included are mechanical specifications such as weight, size, and number and type of controls. The specs and description of the viewfinder are usually given separately, as are accessories, length of cable allowable to reach camera control unit, and any other special features.

Since most of the electrical specs are standard, the user should pay particular attention to illumination requirements, environmental specifications (depending on where the camera is to be used), and portability. The illumination requirements will give the user some idea of the quality of the optical system. The type and amount of primary power is an important consideration for the user in a remote area or in an application where portability is important. The user should inquire carefully as to the pick-up tube type and its reliability. The availability of various types of corrective and compensating controls, monitor switching, and viewfinder performance are other considerations.

There is, of course, another entire series of TV cameras used for closed circuit TV. These cameras are much smaller and simpler, with fixed focus, and usually black and white only. Since they are not usually part of a communications system, they are mentioned only in passing. Such cameras are available from most of the suppliers listed in this section. Examples of smaller, black and white cameras that may be of interest to the public service user are included in Table 4.1-2. Camera suppliers are listed in Table 4.1-3.

Table 4.1-2

TV Camera Specifications Studio Quality

Camera Type	Resolution	Sensitivity (Illumination)	Signal/Noise Ratio	Power Requirements	Environmental (Operating)	Weight (lbs.)	Price
Harris TC-80	600 TV lines	min.w/f 1.6 lens = 6 f_C* For rated S/N at f 2.8 = 80f_C	NTSC 50 dB PAL 47 dB	120/240 VAC 47-63 Hz 500 W	-20° to +50°C R.H. 0-95% Altitude: 10,000 ft.	85	$50,160 less lenses & tubes.
Harris TE-301	500 TV lines	min.w/f 2.0 lens = 10 f_C For rated S/N at f 2.8 = 85 f_C	48 dB	120/240 VAC 60 Hz 195 W	-20° to +40°C R.H. 0-95% Altitude: 10,000 ft.	22	$31,552 w/tubes w/o lenses
Panasonic AK-920	500 TV lines-center 400 TV lines-corner	min.w/f 1.8 lens = 15 fc Recommended: 150 fc @ f 4	luminance: 48 dB	120 VAC 60 Hz 110 W	0° to +40°C R.H. < 90%	55 w/o lens	$30,000 w/tubes w/o lenses
Panasonic WV-3800	260 lines - center	min.w/f 2 lens = 15 fc Recommended: 140 fc @ f 4	luminance: 47 dB	12 VDC 14 W	0° to 40°C	9.9	$4,000 w/tubes w/o lenses
Panasonic WV-380P	750 lines - center	Required: w/ f 1.4 lens = 5 fc	42 dB	117 VAC 60 Hz 20 W	10° to 50°C R.H. < 90%	13.9	$1,200 w/tubes w/o lenses
Panasonic WV-2150	400 lines - center	min.w/f 2 lens = 25 fc normal w/lens f 2.8 = 200 fc	luminance: 46 dB	120 VAC 60 Hz 75 W	0° to 40°C	17.7	$7,500 w/tubes w/o lenses

Table 4.1-2 (cont'd)

TV Camera Specifications Studio Quality

Camera Type	Resolution	Sensitivity (Illumination)	Signal/Noise Ratio	Power Requirements	Environmental (Operating)	Weight (lbs.)	Price
Sony DXC-1210	300 lines - center	min.w/f 2.5 lens = 25 fc Optimum w/lens f 2.5 = 150 fc	luminance: 45 dB	120 VAC ± 10% 60 Hz 65 W	0° to 40°C	50.75	$4,900 w/tubes & lenses
Sony DXC-1650	300 lines - center 250 lines - corner	min: 25 fc Optimum: 150 fc	luminance: 45 dB	120 VAC ± 10% 60 Hz 40 W	0° to 40°C	24	$4,150 w/tubes w/o lenses
Panasonic AK-750P/EN	500 lines	20 fc min. at f1.8	49 dB	-	-15°C to +45°C	16	$22,000
RCA TK-46	600 lines - center	125 fc @ f 4	NTSC 52 dB PAL 49 dB	90-130 V or 190-260 V 47-63 Hz 650 V-A	-20° to +55°C 0-90% R.H. 10,000 ft.	104	$75,200 w/o tubes w/o lenses
RCA TK-47	800 lines - center	125 fc @ f 4	NTSC 52 dB PAL 49 dB	100-120 V or 200-240 V 45-66 Hz 390 W	-20° to +50°C 0-95% R.H. 10,000 ft.	88	$79,600 w/tubes w/o lenses $11,750 for digital
RCA TK-76	400 lines - center	125 fc @ f 2.8	NTSC 51 dB PAL 49 dB	12 VDC 50 W 120/240 VAC 50/60 Hz	-20° to +50°C 0-90% R.H. 10,000 ft.	21.8	$38,400 w/tubes w/o lenses

*fc = foot candles

Table 4.1-2 (cont'd)

TV Camera Specifications Studio Quality

Camera Type	Resolution	Sensitivity (Illumination)	Signal/Noise Ratio	Power Requirements	Environmental (Operating)	Weight (lbs.)	Price
Bosch-Fernseh KCK-KCK/R	Modulation depth w/ a 5 MHz color bar pattern w/ aperture correction = 100%	with f5.6 lens = 150 fc	45 dB	117 or 220 VAC + 5%, -10% 50-60 Hz	-20° to +45°C	36 kg. KCK 7 kg KCK/R (Hand-held)	$73,000 $74,220 w/o tubes w/o lenses
Bosch-Fernseh KCA-90 (Hand-held) (Professional)	20% Modulation on 5 MHz color bar	32.5 fc at f1.4	50 dB	30 w DC 6-8V AC 90-260V DC 11-14V	-20° to +45°C	10 kg.	$39,175 w/tubes w/lenses
IVC-7000	400 lines	8 fc @ f1.6	NTSC 51 dB PAL 49 dB	117 VAC ± 10% 234 VAC ± 10% 50/60 Hz 200 VA	-20° to +50°C 0-90% R.H.	70	$47,500 w/CCU & accessories
Harris TE-50	600 lines	with f1.6 lens = 8 fc For rated S/N w/f2.8 = 100 fc	48 dB	90-130 VAC 50/60 Hz or 180/260 VAC 260 VA	-20° to +50°C RH 0-95% 10000 ft.	75	$32,155 less lenses & tubes
Shibaden 1212							$21,000

Table 4.1-2 (cont'd)

TV Camera Specifications Hand-Held Consumer Quality

Camera Type	Resolution	Sensitivity (Illumination)	Signal/Noise Ratio	Power Requirements	Environmental (Operating)	Weight (lbs.)	Price
Akai VC-8300 (Black & White)	500 lines	5 fc minimum	-	11 watts	-	1.3/4	$395
Quasar VK-100 (Black & White)	450 lines	5 fc minimum	-	9 watts	-	2.1/2	$300
Magnavox VH-8210 (Black & White)	270 lines	5 fc minimum	-	45 watts	-	2.1/4	-
RCA BW-004 (Black & White)	525 lines	5 fc minimum	-	9 watts	-	3	$430
Zenith JC-500 (Black & White)	400 lines	10 fc minimum	-	12 watts	-	2.1/2	$395
JVC G-31	230 lines	9 fc minimum	-	9 watts	-	4	$850
Magnavox 8240	230 lines	10 fc minimum	-	12 watts	-	8	$895
Quasar VK-700	240 lines	10 fc minimum	-	23 watts	-	9	$800
RCA CC-001	-	10 fc minimum	-	29 watts	-	-	$850

Table 4.1-2 (cont'd)

TV Camera Specifications Hand-Held Consumer Quality

Camera Type	Resolution	Sensitivity (Illumination)	Signal/Noise Ratio	Power Requirements	Environmental (Operating)	Weight (lbs.)	Price
Sony HVC-1000	300 lines	10 fc	-	7 1/2 watts	-	5	$1,400
Zenith KC-1000	250 lines	10 fc	-	22 watts	-	4.1/2	$995
Sony AVC-1450 (Monochrome)	450 lines - center	min.w/f 1.4 lens = 0.1 fc	44 dB	120 VAC 60 Hz 13 W	-5° to 45° C	2.1	$395
GBC MK-XII	600 lines	0.2 fc	45 dB	-	0°C to +50°C	5	$274
GBC CTC-3000	600 lines	0.2 fc	45 dB	-	0°C to +50°C	5	$250
GBC MC-2	Microscope CCTV System with CTC-3500 Color Camera & MV-17 17" Monitor					-	$995

Table 4.1-3

TV Camera Suppliers

Harris Corporation Broadcast Products Division P.O.Box 4290 Quincy, Illinois 62301	(217) 222-8200
RCA Broadcast Systems Front and Cooper Streets Camden, New Jersey 08102	(609) 963-8000
Panasonic Company Division of Matsushita Electric Corporation of America One Panasonic Way Secaucus, New Jersey 07094	(201) 348-7000
Sony Corporation of America 9 West 57th Street New York, N.Y. 10019	(212) 371-5800
International Video Corporation 990 Almanor Avenue Sunnyvale, CA 94086	(408) 738-3900
Robert Bosch GmbH Robert Bosch Corporation 6300 Arizona Circle Los Angeles, CA 90045	(213) 649-4330
Akai America, Ltd. 2139 E. Del Amo Blvd. Compton, CA 90220	(213) 537-3880

Magnavox Government & Industrial Electronics Co. (219) 482-4411
1313 Production Rd.
Ft. Wayne, Indiana 46808

Zenith Radio Corp. (312) 391-7000
1000 Milwaukee Ave.
Glenview, Illinois 60026

RCA Distributor & Special Products Div. (609) 963-8000
Cherry Hill Offices
Bldg. 206-2
Camden, NJ 08101

US JVC Corp.
58-75 Queens Midtown Expressway
Maspeth, NY 11378

GBC Closed Circuit TV Corp. (212) 989-4433
315 Hudson St.
New York, NY 10013

NEC America (312) 724-7502
Broadcast Equipment Div.
1948B Lohigh St.
Glenview, IL 60025

4.1.2 Future Trends

4.1.2.1 Solid State Cameras

There are other developments in the video equipment business that should be mentioned in any discussion of processed video. One is the solid-state TV camera with a digital output. General Electric has on the market a solid-state charge-injection-device (CID) camera. Solid-state imaging techniques have been under development for several years, the initial type being a self-scanned photodiode array. Since then, charge-coupled and charge-injection devices have come into use. All of these devices operate, in the simplest sense, on the current generating properties of a semiconductor junction when light energy is allowed to fall on it. The device can be scanned for voltage output versus an x-y address by using column and row electrodes to the array.

Solid-state imagers are more than just a laboratory curiosity, yet they have not come onto the mass-produced market. They are expected to be quite low cost and may well be the major device used for TV cameras by 1980 and beyond. They are advertised now mainly for inspection devices, quality control, sorting and monitoring operations. Microprocessor control of the scan rates plus digital as well as analog outputs make these devices candidates for all sorts of computerized operations. Resolution is a function of the element matrix, much as in slow-scan video equipment. The following table gives the models and prices of GE imagers (see Table 4.1-4).

Devices with a square pixel (picture element) matrix are used to view relatively square objects, while the rectangular array devices are used to observe linear objects. Other specifications of these devices are as follows:

Devices with a square pixel matrix are used to view relatively square objects, while the rectangular array devices are used to observe linear objects. Other specifications of these devices are as follows:

Power Source	±15V at 50 ma.
Weight	18-21 oz.
Temperature	0° to 50° C
Altitude	to 50,000 ft.
Digital Output	TTL Compatible
Video Output	1 V p-p @ 75 Ω

Table 4.1-4

Solid-State Imagers

Vendor	Model	Description	Price
General Electric*	4TN2200A1	128 x 128 pixels	$ 995
	4TN2200B1	w/Remote Sensor	$1295
	4TN2201A1	40 x 340 pixels	$1995
	4TN2201B1	Remote Head Version	$2295
	4TN2110A1	Support & Interface Module for above cameras	$1195
	4TN2500A1	244 x 248 pixels	$3000

*General Electric
Optoelectronic Systems Operations
Building 3, Room 201, Electronics Park
Syracuse, New York 13201
(315) 456-2832

4.2 VIDEO TAPE RECORDERS.

4.2.1 General Description and Specifications

The video tape recorder is an electromechanical device which is used to deposit or recover a composite video waveform from magnetic tape. There are four basic parts to the video tape recorder:(1)

1. The tape transport-this is the mechanical system that moves the tape over the recording and playback heads.
2. The servo control-used to control precisely the velocity of the tape over the recording heads.
3. The recording electronics-amplifiers and other components used to process the signal before recording.
4. The playback electronics-used to process the signal before playback. Provides equalization, amplification and adds new sync and color burst signals.

An important feature of any tape recorder system is its bandwidth, and bandwidth is proportional to tape speed. In order to achieve the extremely wide bandwidths required for video signals, both the recording heads and the tape move in opposite directions in a video tape recorder. The relative motion between the two components is thus increased, and the bandwidth is increased proportionately. Specifications show the tape speed and the relative speed (writing speed). In some recorder types, the recording tracks are oriented almost at 90^0 to the direction of tape movement and more than one tape head is used, with the signal multiplexed from one head to the next as each comes into contact with the tape. Four different tracks are deposited on a video tape: video, audio, cue, and timing control.

An important specification of tape recorders is concerned with tape velocity control. The tape servo control system must therefore be of high quality to maintain relative tape-to-head velocity within very small limits. The control track is used to aid in this velocity control, as are waveform and picture monitors. Wow and flutter are the specifications which describe the quality of tape velocity control.

The video signal is not recorded directly onto the tape using amplitude modulation because very small tracking errors would cause large signal variations. Instead, the signal is applied to a frequency modulator, thus making the amplitude of the recovered signal independent of the amplitude of the RF signal.

Tape machines generally fall into three classifications: high band, low band, and switchable high/low band. This nomenclature is concerned with the FM deviation and modulation sensitivity used in recording. The use of the color subcarrier for color recording requires higher deviation linearity than monochrome recording, thus high band recorders are always preferred for either monochrome or color. Because large tape libraries are already in existence which were recorded using low band, a switchable high/low band recorder is desirable. The low band carrier frequency range is between approximately 4.7 to 5.8 MHz for the FM deviation. The high band oscillator and modulating frequency is in the 100MHz region with deviation only a few megahertz, i.e., deviation is only a few per cent and thus very linear. The sum of the two frequencies results in a frequency swing around 8 MHz. Deviation is approximately 7 MHz at sync tip to 10 MHz at peak white.

One other specification often seen in video equipment is differential gain/phase. Differential gain is defined as the difference in gain encountered by a low-level, high frequency sinusoid at two stated instantaneous amplitudes of a superimposed high level, low frequency signal. Differential phase is the difference in phase shift under the same conditions. Differential gain and phase are therefore a measure of intermodulation or crosstalk between the luminance (whiteness or brightness) signal and the chrominance (color difference) signals in video processing circuits.

Video tape recorders are available as reel-to-reel recorders and as cassette machines. The reel-to-reel machines are of higher quality and capability and are more often used for broadcast work. A specification comparison is given in Table 4.2-1

The specifications of Table 4.2-2 cover two major categories of video tape recorders. The first is broadcast or studio quality machines. These machines are quite a bit more expensive than the consumer variety given also in the table. However, the specs do not vary a great deal in terms of S/N ratio, bandwidth and some other standard performance features. The differences in the two types lie more in the additional capabilities available in the professional types for editing, monitoring and other studio work. Notably, video specs such as pulse response (to a 2T $\sin^2$ pulse; a standard test waveform), and color Moiré are not often given for the consumer varieties. Speed control and selection is another feature of the studio recorders. Specifications for differential gain and phase give information on what happens to the gain and phase of a weak signal in the presence of another stronger signal in the same equipment. This specification is important in maintaining the accuracy and proper level of color signals.

(1) Television Systems Measurements, G. A. Eastman.
Published by Tektronix, Inc., Beaverton, Oregon, 1969

Table 4.2-1
Videotape Recorder Specifications

Reel-to-Reel		Cassette
96 minutes	Recording Time	1 hour
9.6 ips	Tape Speed	3 3/4 ips
1000 ips	Writing Speed	40 ft./sec.
90 seconds	Shuttle Speed (FF/REV)	Less than 6.0 minutes
0.1% rms,NAB unweighted	Wow/Flutter	0.2% rms
High band direct FM	Recording System	FM,low frequency conversion, subcarrier phase shift
7.05-10 MHz	Carrier	-
30 Hz-4.2 MHz ± 0.5dB	Bandwidth	-
48 dB V(p-p)to rms noise	S/N Ratio	46 dB
4%	Differential gain	-
4°	Differential Phase	-
1% (2T Pulse)	Transient Response(K factor)	-
-40 dB (75% Color bar)	Moiré	-
40 nsec.	Chrominance/Luminance Delay	-
1 microsec (p-p)	Time base stability	-
	Input Signal	
1± 0.3V p-p @ 75ohms	Video	1.0 V p-p @ 75ohms
4± 1.0 V (p-p)	Sync	4 V p-p 75 ohms
2± 0.5 V (p-p)	Subcarrier	2V p-p 75 ohms
	Output Signal	
1.0 V p-p @ 75 ohms	Video	1.0 V p-p @ 75 ohms
4.0 V p-p 75 ohms	Sync	
50Hz-15KHz	Audio Response	50-15000 Hz
56 dB	Audio Signal/Noise	48 dB
1%	Distortion	3%
-50 dB	Crosstalk	
+4, +8,+10 dbm,600/150ohms, bal.	Output Signal	-5 dB,100K ohm load, unbal.
AC 100-120/220-240	Power Requirements	120±12 Vac 50 or 60 Hz ±0.5%
700 W. max.	Power Consumption	130 Watts
5°C to 40°C	Operating Temperature	5°C to 40°C
22.6 "x35" x 26.1"	Dimensions	25½ x 9"x18¼"
265 lb.	Weight	75 lb.

Table 4.2-2

VTR Specifications Studio Quality

Manufacturer	Model	Type	Bandwidth	Pulse Response K-factor w/2T sine^2 Pulse	S/N Ratio	Color Moiré at 3.58 MHz (dB)	Differential Gain & Phase	Price
Ampex	ACR-25B NTSC Color System w/wave form, vector, & color monitors	Cassette color	Flat to 4.5 MHz -3 dB at 5 MHz ±0.5 dB	1%	46 dB p-p video/rms noise	-40	3% & 3°	$223,510
Ampex	VPR-2 Tabletop Recorder/Reproducer	Reel-reel	Flat to 4.2 MHz ±0.5 dB -3 dB @ 5 MHz	1%	46 dB p-p video rms noise	-40	4% & 4°	$39,000
Ampex	VPR-20 Portable	Reel-reel	Flat to 4.5 MHz ±0.5 -3 dB @ 5 MHz	1%	46 dB	-40	4% & 4°	$36,300
Ampex	AVR-2 w/waveform, vector, & color monitors	Reel-reel color	Flat to 4.8 MHz -3 dB @ 4.85 MHz	1%	46 dB 43 dB	-40	4% & 4°	$96,025
IVC	IVC-9000 (color)	Reel-reel	Flat to 5.5 MHz -3 dB @ 6.0 MHz ±0.5 dB	1%	46 dB	-40	2% & 2°	$74,500
RCA	TH-200	Reel-reel	30 Hz - 4.2 MHz ±0.5 dB	1%	47 dB	-40	4% & 4°	$45,000
Bosch-Fernseh	BCN-50	Reel-reel	4.2 MHz ± 0.5 dB 5.0 MHz - 3 dB	1.5%	47 dB	-37	4% & 4°	$78,700
RCA	TCR-100A	Cartridge	30 Hz - 4.1 MHz ±0.5 dB -3 dB @ 4.3 MHz	1%	46 dB	-40	4% & 4°	$218,500 basic w/ signal processing

Table 4.2-2 (cont'd)

VTR Specifications Studio Quality

Manufacturer	Model	Type	Bandwidth	Pulse Response K-factor w/2T sine² Pulse	S/N Ratio	Color Moiré at 3.58 MHz (dB)	Differential Gain & Phase	Price
IVC	IVC-1070C	Reel-reel Teleproduction	30 Hz - 4.0 MHz	-	47 dB	-	-	$13,500
	IVC-1070 (monochrome)	"	" "	-	"	-	-	$12,450
IVC	IVC-870 (monochrome)	Reel-reel Insert/ Edit	30 Hz - 3.5 MHz ±1 dB	-	42 dB	-	5%	$8,400
Sony	BVH-1000A	Teleproducer reel-reel		-	-	-	-	$41,000
	BVU-200A	Reproducer		-	-	-	-	$9,950
	BVE-500	Prof. Editor Console		-	-	-	-	$5,500
Sony	VO-2860	Editing Cassette		-	-	-	-	$6,625

Table 4.2-2 (cont'd)

VTR Specifications Consumer Quality

Manufacturer	Model	Type	Tape Speed	S/N Ratio	Environmental	Power Consumption	Price
Panasonic	NV-3085	Cassette portable	7.1/2 ips	40 dB	5° - 40°C 35-80% RH	12 watts (12 VDC)	$1,300
Panasonic	NV-8400	Cassette portable	1.5/16 ips	45 dB	5°C - 40°C	9.5 watts (12 VDC)	$1,300
Sony	AV-3400	Portable Cassette	7.1/2 ips	40 dB	0° - 40°C	12 watts	$1,295
General Electric	9000	Cassette	-	40 dB	-	45 watts	$1,100
Sony	Betamax SL-8600	Cassette	-	45 dB	-	80 watts	$1,095
Zenith	KR-9000	Cassette	-	40 dB	-	80 watts	$995
RCA	Selectavision 200	Cassette	-	40 dB	-	36 watts	$1,000
Quasar	VR-1000	Cassette	-	40 dB	-	98 watts	$995
Magnavox	8200	Cassette	-	40 dB	-	45 watts	$1,085
Philco	V1000	Cassette	-	43 dB	-	28 watts	$995
Panasonic	NV-8310	Cassette	1.5/16 ips	45 dB	5°C - 40°C	24 watts	$1,300
GBC	TL-125	Cassette time laps	-	-	-	-	$3,750

Table 4.2-3

Video Tape Recorder Suppliers

Ampex Corporation Audio-Video Systems Division 401 G Broadway Redwood City, California	(415) 367-2011
RCA Broadcast Systems Front and Cooper Streets Camden, New Jersey 08102	(609) 963-8000
International Video Corporation 990 Almanor Avenue Sunnyvale, CA 94086	(408) 738-3900
Panasonic Company Division of Matsushita Electric Corporation of America One Panasonic Way Secaucus, New Jersey	(201) 348-7000
Sony Corporation of America 9 West 57th Street New York, NY. 10019	(212) 371-5800
Robert Bosch Corporation 6300 Arizona Circle Los Angeles, CA 90045	(213) 649-4330
GBC TV Corp. 315 Hudson St. New York, NY 10013	(212) 989-4433
NEC America, Ltd. Broadcast Equipment Div. 1948B Lohigh St. Glenview, IL 60025	(312) 724-7502

4.2.2 Future Trends

Developments in video tape recorders are taking place at two levels. In existing magnetic tape recorders, the advent of one-inch, helical VTR's for high-quality studio/broadcast production is important. There have been format problems and variations in all aspects of video development since its outset. These problems are not particularly alleviated by the helical recording technique.

Conventional quadruplex VTR's use four video heads which rotate at right angles to the tape movement thus laying down a video track at almost a right angle to the tape movement. The helical technique, while not really new, wraps the tape in a spiral around the recording drum. These techniques have facilitated editing and copying, as well as having lower acquisition costs, reduced volume and weight, lower power consumption, and lower operating costs.

In the lower cost, consumer VTR field, format problems also persist, but most efforts seem to be going toward more and cleverer gadgets, such as long-period timers, start/stop/pause controls, and multichannel recording.

In an entirely different segment of research, the video disc recorder seems to be the wave of the future. Using optical recording techniques, lasers, and exotic materials, the video disc recorder, when fully developed, may make the magnetic tape recorder obsolete. Problems persist in mechanical and electromechanical controls and servos for the recorder, and in materials development for the disc itself. Rotating the disk on a 1800 rev/min. turntable, using a laser light source with modulator, it is expected that a 30 cm. diameter disk should be able to record a signal with 20 MHz bandwidth for at least a half-hour program.

Attractiveness of these devices will be enhanced by development of reusable and erasable recording materials, and by development of lower power consumption GaAs lasers for recording and playback.

4.3 VIDEO MONITORS.

4.3.1 General Description & Specifications

A video monitor differs from a television receiver in that the monitor does not receive and downconvert RF signals, but rather has as its input the composite baseband video pulses that make up the TV signal. Thus the monitor can be used in the studio or with other equipment to display the picture coming from a camera or video tape recorder. The display tube and deflection circuits are the same as a regular TV set.

Video monitors are available in individual packages, in multiple display packages for studio use, and they often are packaged as part of other studio equipment such as video tape recorders or mixer consoles.

Monitors are available also in high precision studio quality computer and graphics displays and standard, lower cost varieties. They can be bought for black/white or color. The brightness specification should be noted in terms of the application light environment. Power requirements and weight plus size of screen vary with the type and application. The user should be cognizant of OSHA radiation requirements on TV monitors and displays and check with suppliers for compliance.

Table 4.3-1

Video Monitor Specifications

Video System	EIA 525 line, 60 fields
Color System	NTSC, PAL, and SECAM (selectable)
Picture Tube	Trinitron 25 in. diagonal
Video Input	LINE IN (BNC Connector)
	VTR (8-pin connector)
	1.0V p-p, 75ohms
Video Output	LINE OUT (BNC Connector)
	1.0V p-p, 75 ohms
Sync Input	4.0V p-p $\pm$ 6 dB negative
	75 ohms
Return Loss	More than 32 dB, dc-5MHz
Frequency Response	100 KHz to 4.0 MHz $\pm$ 2.0dB
DC Restoration	Back Porch type
Resolution	Center-more than 350 TV lines
	Corner-more than 270 TV lines
Chroma Bandwidth	Within -4dB at 3.58 MHz $\pm$ 0.5 MHz
Brightness	Center 55F.L. nominal with APL 100%.
	Corner 40 F.L. nominal with APL 100%
Power Supply	120 V AC 60 Hz
	230 W maximum
Dimensions	25 5/32" x 25 3/[illegible]" x 20 $\frac{1}{16}$" (w/h/d)
Weight	187 lb. 6 oz.

Table 4.3-2

Video Monitors

Manufacturer	Model/Type/Application	Video Frequency Response	Display Size Inches	Maximum Usable Brightness	Center Resolution (Horizontal)	Power Requirement	Weight (lbs.)	Price
Conrac	DZB/Mono Professional/ Industrial	10 Hz - 10 MHz ± 1 dB	15	-	-	80 watts	60	$1,470 - $1,600
	ENA/ - /Mono Educational/ Industrial	100 Hz - 10 MHz ± 1.5 dB	9,12	-	650 lines	45 watts	15-23	$400 - $480
	SNA/ - /Mono Professional/ Industrial	60 Hz - 10 MHz ± 1 dB	9,14	50 fL	800 lines	95 watts	32-76	$770 - $980
	QQA/ - /Mono TV, computer	± 1 dB to 30 MHz	14.17	50 fL	1000 lines	150 VA	51-65	$2,020 - $2,240
	5200 Series Industrial/ Educational	± 1 dB to 5.5 MHz	19,25	60 fL	450 lines	125 watts	99-146	$2,750 - $3,475
	5300 Series Broadcast/ Production	± 1 dB to 5.5 MHz	19	60 fL	450 lines	125 watts	99	$3,200 - $3,280
	5211) Alphanumeric,	100 Hz - 10 MHz	19	60 fL	500 pixels	125 watts	99	$2,550
	5411) Computer,	± 1 dB	19	60 fL	750 pixels	125 watts	99	$4,700
	5711) Graphic RGB		13	80 fL	620 pixels	100 watts	50	$3,810
	5700 Series Broadcast/ Production	± 1 dB to 5.5 MHz	13	80 fL	500 lines	100 watts	50	$3,730 - $4,330

Table 4.3-2 (cont'd)

Video Monitors

Manufacturer	Model/Type/ Application	Video Frequency Response	Display Size Inches	Maximum Usable Brightness	Center Resolution (Horizontal)	Power Requirement	Weight (lbs.)	Price
Conrac	6122 6142 Professional/ Broadcasting/ Production	100 Hz - 6.5 MHz ±1 dB	19	60 fL	625 lines	140 watts	90	\$5,510 \$6,250
Sony	PVM-5300 Triple 5"	-	5	-	-	105 watts	52	\$2,200
	PVM-1211	-	13	-	-	105 watts	59	\$1,450
	PVM-2550	100 Hz - 4.0 MHz ±2 dB	25	55 fL	350 lines	230 watts	187	\$3,000
	PVM-8000	-	8	-	-	45 watts	18	\$795
	PVM-1850PS	-	17			-	71	\$1,430
	PVM-410 Quadruple 4"	5 MHz +3,-0 dB	4	-	400 lines	52 watts	35	\$1,130
	CVM-131 Mono Monitor/Receiver	-	13	-	-	35 watts	19	\$355
	CVM-194 Mono/Monitor/ Receiver	-	19	-	-	65 watts	46	\$445
	CVM-194U Mono/Monitor/ Receiver	-	19	-	-	53 watts	44	\$445

Table 4.3-2 (cont'd)

Video Monitors

Manufacturer	Model/Type/ Application	Video Frequency Response	Display Size Inches	Maximum Usable Brightness	Center Resolution (Horizontal)	Power Requirement	Weight (lbs.)	Price
Sony	CVM-960 Mono/Monitor/ Receiver	-	8	-	-	23 watts AC 12 watts DC	12	$335
Panasonic	WV-760	10 MHz	5	-	600 lines	27 watts	10	$300
	WV-5203	10 MHz	5	-	600 lines	81 watts	37	$700
	WV-5300	10 MHz	8.1/4	-	700 lines	30 watts	13	$300
	WV-5301	10 MHz	8.1/4	-	700 lines	30 watts	19	$320
	WV-5302	10 MHz	8.1/4	-	700 lines	60 watts	30	$600
	WV-5310	10 MHz	8.1/4	-	700 lines	38 watts	14	$400
	WV-5311	10 MHz	8.1/4	-	700 lines	32 watts	19	$450
	WV-5312	10 MHz	8.1/4	-	700 lines	64 watts	31	$800
	WV-5400	10 MHz	12.3/4	-	700 lines	35 watts	23	$350
Bosch-Fernseh Precision	Color MC37 BA MC51 BA							 $5,150 $8,140
High Quality	Color MC37 BB MC51 BB							 $3,660 $5,160

Table 4.3-2 (cont'd)

Video Monitors

Manufact-urer	Model/Type/ Application	Video Frequency Response	Display Size Inches	Maximum Usable Brightness	Center Resolution (Horizontal)	Power Requirement	Weight (lbs.)	Price
Tektronix	650A Series	-	7.2 x 9.6	30 fL	-	150 watts	52	$4,005.
	653A/ 656A	±0.5 dB to 6 MHz	7.2 x 9.6	30 fL	-	150 watts	52	$4,985/ $5,545
	670A		10.1 x 13.5	30 fL	-	230 watts	89	$3,785
GBC	MV-50	Flat to 9 MHz	5 inch diag.	-		24 VA	7	$348
GBC	MV-17	-	17 inch diag.		800 lines	80 VA	39	$575

Table 4.3-3

Video Monitor Suppliers

Sony Corporation of America 9 West 57th St. New York, N.Y. 10019	(212) 371-5800
RCA Broadcast Systems Front and Cooper Streets Camden, New Jersey 08102	(609) 963-8000
Panasonic Company Division of Matsushita Electric Corporation of America One Panasonic Way Secaucus, New Jersey 07094	(201) 348-7000
Conrac Division Conrac Corporation 600 North Rimsdale Ave Covina, California 91722	(213) 966-3511
Robert Bosch Corp. 6300 Arizona Circle Los Angeles, CA 90045	(213) 649-4330
Tektronix, Inc. P.O. Box 500 Beaverton, Ore. 97077	(503) 644-0161
GBC TV Corp. 315 Hudson St. New York, NY 10013	(212) 989-4433

4.3.2 Future Trends

The state of the art in video monitors may not strike one as a field ripe for new developments, yet all of the technological advances in TV receivers apply to video monitors as well. The main thrust of work in this field is in the development of thin-screen displays and new types of displays to replace the conventional CRT with a flat, very thin screen.

One such technique is the electroluminescence panel which uses pulses to alternately polarize and depolarize electrodes built into the screen. Resolution of 2.7 lines/mm. is reported on a screen about 50 mm. thick. The other technique is the liquid-crystal display (LCD) which has been used to develop a pocket-sized monochrome display. Both techniques provide an array on the order of 240 x 240 picture elements. Integrated circuit techniques are used to deposit various compounds and doped semiconductors on the substrate which forms the front surface of the screen. More work must be performed on these techniques to achieve acceptable contrast, brightness, and color.

4.4 VIDEO PROJECTION EQUIPMENT.

4.4.1 General Description & Specifications

A more recent development in the video product area is the large screen TV projection system. This system combines the versatility and timeliness of TV programming with the capability for large screen viewing inherent in motion pictures. Both black-and-white and color TV projectors are available now, and these projectors take the standard video signal (1.0V.p-p at 75 ohms) and project the image on a screen whose size is anywhere from two feet to twenty feet on a side. The main applications for these projectors are found where large audience viewing of a TV program is desired. In a strictly entertainment sense, this would include closed circuit TV or TV programs shown in hotel lounges or other public meeting places. For the public service user, the applications for educational TV and medical or business conferencing are obvious.

Video projection systems are not cheap, but their use where large audience viewing is desired makes them a worthwhile investment and a viable force on the market. The video projector does not simply use a conventional TV tube and optics to focus the image on a screen. Rather, in a color projector, lenses and optics are used to project the basic three colors from three special video beam tubes on to the screen, thus providing higher light intensity.

Table 4.4-1 is a general specification of these projectors. Table 4.4-2 lists a number of projector-screen systems and some comparative specifications. Table 4.4-3 lists suppliers of these equipments.

Table 4.4-1
Video Projector Specifications

Power Input	115V/60 Hz/150 watts
External Video Input	NTSC Color Standard .5-2V p-p, 75 ohms. PAL, SECAM optional
External Audio Input	0 dB, 2 K ohm, unbalanced
RF Input	VHF: 75 ohm channels 2-13
	UHF: 300 ohm channels 14-83
Audio Output	3 watts RMS to built-in speaker
Audio Line Output	600 ohm variable volume
Resolution	better than 280 lines
Optical	3- 3"CRT, RGB
Optics Size	Mirror Diameter 7.5"
	Corrector Lens Diameter 7.0"
Light Output	70 lumens average
	200 lumens highlight brightness

Screen Size	Projector Distance from Screen	Highlight Brightness (Foot Lamberts)
4 1/2' x 6'	10'8"	15 FL
5 1/4' x 7'	12'6"	11 FL
6' x 8'	14'4"	8.4 FL

Mechanical	
Projector	31" x 29" x12"
Weight	125 lb.
Control Box	5" x 8 1/4" x 2 3/4"
Weight	2 lbs.

Table 4.4-2

Comparative Specifications of TV Projectors

Manufacturer	Model	Diagonal Screen Size	No. of pieces	Screen to Projector Distance (ft)	Image Source	Console weight (lbs.)	Suggested Retail Price
Advent	Videobeam 710	5 ft.	2	6	Projection tubes	105	$2,595
Advent	" 750	6 ft.	2	7	Projection tubes	105	$2,995
Advent	" 760	6 ft.	2	7	Projection tubes	110	$3,300
Advent	" 1000A	7 ft.	2	8	Projection tubes	140	$3,995
Audiographix	Audiographic V.P.	5.1/2 ft.	2	5.1/2	TV	67	$1,295
Extron	VS-700	50 inches	2	5	TV	80	$625 (excl. TV)
Extron	VS-1000	50 inches	1	-	TV	180	$825 (excl. TV)
General Electric	Widescreen 1000	45.3/4 inches	1	-	TV	359	$2,800
Mitsubishi	Video Scan	6 ft.	2	6.1/2	Projection tubes	193	$3,400
Panasonic	CT-6000	5 ft.	1	-	Projection tubes	180	$3,800
Projector Beam	Projector Beam	5 ft.	2	5.1/2 - 6	TV	60	$999
Quasar	Great Show Machine	5 ft.	1	-	Projection tubes	170	$4,500
Sharp	7200	6 ft.	2	7	Projection tubes	154	N/A
Sony	KP-5000	50 inches	1	-	Projection tubes	N/A	N/A
Sony	KP-7200	6 ft.	1	-	Projection tubes	N/A	N/A

Table 4.4-2 (cont'd)

Comparative Specifications of TV Projectors

Manufacturer	Model	Diagonal Screen Size	No. of pieces	Screen to Projector Distance (ft)	Image Source	Console weight (lbs.)	Suggested Retail Price
Video Concepts	Concepts 5000	64 inches	2	5.1/2 - 6	Projection tubes	150	$2,595
Projection Systems, Inc.	230	2.1/2 - 15 ft.	2	-	Projection tubes	90	
Video Industries	Videomaster	52 inches	1	-	TV	170	$1,695
Viewpoint	V-3000	50 inches	2	6	TV	75	$699 (excl. TV)
Viewpoint	V-4000	50 inches	1	-	TV	200	$1,399 (excl. TV)

Source: Video Magazine Buyer's Guide - 1979

Projection Systems	560	6 - 12 ft.	2	12 - 24	Projection tubes	350	
"	270A	6 - 20 ft.	2	12 - 40	Projection tubes	200	

Table 4.4-3

Video Projector Suppliers

Projection Systems, Inc. 517 Van Houten Ave. Passaic, New Jersey 07055	(201) 473-0180
Advent Corporation 195 Albany St. Cambridge, MASS 02139	(617) 661-9500
Sony Corporation 9 West 57th St. New York, N.Y. 10019	(212) 371-5800
Extron Co. 8039 G Lewis Rd. Minneapolis, MI 55427	(612) 544-4197
General Electric Co. Microwave and Imaging Devices Dept. G 316 E. 5th St. Owensboro, KY 42301	(502) 926-8600
Panasonic Company Division of Corp. of America One Panasonic Way Secaucus, NJ 07094	(201) 348-7000
Mitsubishi Electric Corp. Tokyo 100, Japan	(03) 218-2111

4.4.2 Future Trends

Video projectors will benefit from improved technology in imaging devices and display techniques as well as circuit techniques such as VLSI. The next few years will be characterized by price decreases accompanied by smaller, lighter consoles. Coupled with slow-scan video, and increased satellite communications, video projectors will find greater acceptance for teleconferencing and educational TV.

4.5 SATELLITE VIDEO DEMODULATORS/MODULATORS

4.5.1 General Description and Specifications

The satellite video demodulator is a fairly recent development on the satellite equipment market. It has been developed in a somewhat synergistic series of events emanating from the CATV industry. A little over a year ago, only one or two manufacturers offered video demodulators for the direct reception of satellite TV signals. Now about a dozen vendors have equipment on the market. The equipment is characterized by simple, one unit designs with modular plug-ins usually available, and low prices.

Satellite video signals are modulated using FM* techniques rather than vestigial sideband techniques as in the broadcast TV band. Variable bandwidths and deviations are usually available depending on particular requirements. These demodulators operate with microwave inputs (i.e., at 4 GHz) and output a standard composite video signal of 1 volt p-p at 75 ohms. Usually the audio signal is modulated as a subcarrier on the main video carrier, so audio subcarrier demodulators strip this signal off and make it available on a separate audio output. More than one subcarrier can be provided.

Other specifications given are the more familiar TV and audio specifications such as differential gain and phase, distortion, and frequency response. Clamping in these receivers is used to remove a very low frequency energy spreading signal added at the uplink modulator to distribute energy around the carrier somewhat when no program modulation is present. This spreading waveform is needed to reduce the peak of the carrier spike for interference reasons. Emphasis and de-emphasis are used to increase the S/N ratio because of the FM receiver noise characteristic.

Threshold for a normal FM limiter-discriminator receiver is at about 10 dB carrier-to-noise ratio. The use of phaselock loops extends this threshold down to 7 or 8 dB, and these techniques result in threshold extension demodulators (TED). The user should note the deviation, bandwidth, carrier-to-noise ratio and weighting used by a given manufacturer in quoting the signal-to-noise ratio for a receiver.

* FM - frequency modulation.

Table 4.5-1 presents a set of typical satellite video demodulator specifications. Table 4.5-2 compares models and prices of a number of such demodulators now on the market. Most of the manufacturers noted also supply exciters or uplink video modulators. Table 4.5-3 list suppliers of satellite video demodulators and modulators.

Table 4.5-1

Satellite Video Demodulator Specifications

IF Frequency	70 MHz
IF Bandwidth	17.5, 20, 25, 30, 36, 40 MHz
Threshold C/N	8.0 dB, if Threshold Extension 10.0 dB if lim-discrim
Signal-to-Noise Ratio	53 dB at 16 dB C/N. p-p deviation 22 MHz. IF bandwidth, 36 MHz. CCIR weighted.
Deviation Range	5-12 MHz peak at de-emphasis crossover frequency
Video Output Freq. Response	10 Hz to 4.25 MHz for 525/60 line format
Output Impedance (video)	75 ohms
De-emphasis	525 or 625 lines per CCIR REC. 405-1
Level (video output)	1 volt p-p
Clamping	50 dB for 30 Hz waveform
Differential Gain	±0.2 dB max, 10-90% APL
Differential Phase	< ±1°, 10-90% APL
Audio Subcarriers	6.2, 6.8, 7.5 MHz, others available
Audio Frequency Response	20-15,000 Hz, ±0.5 dB
Signal-to-hum	58 dB
De-Emphasis	75 μsec time constant
Output Level	0 - 10 dBm at 600 ohms
Impedance	600 ohms
Harmonic Distortion	1% max.

Table 4.5-2

Video Demodulator Equipment

Manufacturer	Model	Outputs	Tunability	Demod Type	S/N	Weight (lbs.)	Power Consumption (watts)	Envir- onment	Price
Microwave Associates	VR-3	2 Video 1 Composite 1 Audio	Fixed	Lim-Discrim		28	100	0° to +40°C	$3,800
	VR-4		Frequency Agile						$6,500
Terracom	FSR	Video Audio 70 MHz Composite	Fixed Tuned	Threshold Extension	55 dB at 17 C/N	45		-10° to +50°C	$5,960
	SR	Video Audio Composite	Tunable Selector	Threshold Extension	58 dB	45	-10° to +50°C		$6,490
	SR-3	Video 2 Audio Composite	Tunable Selector or Programmable	Threshold Extension	58 dB	45	-10° to 50°C		$8,415
Hughes	SVR-462	Video Audio	24 channel Switch selectable	TED	Threshold 55 dB C/N	15	25	0° to 50°C	$4,300
	SVR-461	Video Audio	24 Channel Switch or Remote Digital	TED	Threshold 55 dB C/N	15	25	0° to 50°C	$4,700
ITT Spacecom	TVR 3700	1 Video 2 Audio	Front Panel or Remote Tunable	Threshold Extension	52 dB at C/KT =140 dBW/oK		80 - 100		

Table 4.5-2 (cont'd)
Video Demodulator Equipment

Manufacturer	Model	Outputs	Tunability	Demod Type	S/N	Weight (lbs)	Power Consumption (watts)	Environment	Price
Microdyne	1100 FFC (XI)	Video Audio	Crystal Change & Preselector Tune	TED	Threshold at 8 dB C/N	10	20	0° to 50°C	$3,200
	1100 FFC	Composite Video & Audio	Thumbwheel Select 12 channel	TED	Threshold at 8 dB C/N	20	30	0° to 50°C	$5,200
Scientific-Atlanta	6602	Video/ Audio	Frequency agile	-	7.5 dB C/N Threshold	25	-	0° to 50°C	$3,700
	6601	1 Video 3 Audio	Fixed Tuned	TED	7.5 dB C/N Threshold	25	-	0° to 50°C	$2,775
Farinon	EST-3001	Composite, Video Audio 70 MHz	Fixed Tuned Crystal Change	-	48 dB at 10 C/N	30	100	0° to 50°C	$3,990
	FV4-F	Composite, Video Audio 70 MHz	Fixed Tuned Switchable 24 channel	-	48 dB at 10 C/N	50	130	0° to 50°C	$8,245
SCI	SR-4000	1 Video 2 Audio	Fully agile. Synthesized 24 channel selectable	TED	-	-	-	-	$4,500
	SR-5000	"	Fixed Tuned	TED	-	-	-	-	$3,200

C-3

Table 4.5-2 (cont'd)

Video Demodulator Equipment

Manufacturer	Model	Outputs	Tunability	Demod Type	S/N	Weight (lbs.)	Power Consumption (watts)	Environment	Price
Miteq	REC-TV-70 70 MHz input	Video Audio	Demod only	-	-	-	-	0° to 50°C	$2,500
	TVRO-DC 3.7 - 4.2 GHz		Frequency agile 12 channel	-	-	-	-	0° to 50°C	$5,000
	Single Conversion DownConverter/ RCVR		Single channel Fixed Tuned	-	-	25	-	0° to 50°C	$4,000
Comtech	RCV-450A	2 Video 2 Audio	Local/Remote Continuously Tunable	TED	8 dB C/N Threshold	20	30 VA	10° to 40°C	$5,200
	RCV-450F	"	Fixed Tunable	TED	"	20	30 VA	10° to 40°C	$3,100
LNR	DRV-4 (to INTELSAT spec)	Composite Audio Video 70 MHz	Synthesized Thumbwheel Fixed	TED or Lim-discrim	9-10 dB Threshold		120	0° to 50°C	$16,500
	DRV-4 (to INTELSAT spec)	"	Frequency agile		9-10 dB Threshold		120	0° to 50°C	$17,000
Rockwell-Collins (Special)	55U3-(1)SC Broadcast Spec	2 video 1 composite	Frequency agile	Lim-discrim	63 dB at C/N=25 dB 13.5 MHz peak deviation	46	120	0° to 41°C	$13,000

Table 4.5-2 (cont'd)

Video Demodulator Equipment

Manufacturer	Model	Outputs	Tunability	Demod Type	S/N	Weight (lbs.)	Power Consumption (watts)	Envir-onment	Price
Rockwell-Collins (Special)	53A1-1SC Broadcast Spec	Transmitter	Frequency agile	-	-	-	160	0° to 50°C	$18,000
"	SVR4A	Video & composite	Frequency agile	TED	<8 dB	15	60	0° to 50°C	$5,500
"	SVR4F	"	Field tunable no crystal or filter change required	TED	<8 dB	14	45	0° to 50°C	$3,500

Table 4.5-3

Video Modulator/Demodulator Vendors

Microwave Associates
Communications Equipment Group
Burlington, MA 01803
(617) 272-3100

Terracom, Div. of Conic Corp.
a Loral Subsidiary
9020 Balboa Avenue
San Diego, CA 92123
(714) 278-4100

Hughes Microwave Communications Products
3060 West Lomita Blvd.
Torrance, CA 90505
(213) 534-2146

ITT Space Communications, Inc.
69 Spring St.
Ramsey, NJ 07446
(201) 825-1600

Microdyne Corporation
P.O. Box 1527
Rockville, MD 20850
(301) 762-8500

Farinon Electric
1691 Bayport
San Carlos, CA 94070
(415) 592-4120

Scientific-Atlanta, Inc.
3845 Pleasantdale Road
Atlanta, GA 30340
(404) 449-2000

Scientific Communications, Inc.
3425 Kingsley
Garland, TX 75041
(214) 271-3685

Miteg, Inc.
100 Ricefield Lane
Hauppange, NY 11787
(516) 543-8873

Comtech Laboratories
135 Engineers Road
Smithtown, NY 11787
(516) 231-5454

LNR Communications, Inc.
180 Marcus Boulevard
Hauppauge, NY 11787
(516) 273-7111

Rockwell International
Collins Transmission Systems Division
Commercial Telecommunications Group
P.O. Box 10462
Dallas, TX 75207
(214) 996-5000

4.5.2 Future Trends

The next few years in the satellite video industry probably will be marked more by an increasing proliferation of suppliers and rapidly dropping prices more than by any startling technical breakthroughs. The present forecasts for the number of CATV receivers and head-end companies indicates nothing short of explosive growth for the industry. Manufacturers will probably compete on the basis of increased modularity and flexibility and by lowering prices on the basis of volume production. Increased use of LSI will probably have some impact, and continuing developments in the technology of phaselock loops and FM-feedback will allow lower thresholds to be advertised.

We can also expect the matter of channel tuning to go in two directions. Manufacturers will probably offer models in which sophisticated multi-channel digital or computer controlled channel tuning for up to 36 channels is available, and also they will offer smaller, very simple fixed-tuned models. The satellite video reception market will be exploited for video conferencing and information transfer using slow-scan or processed video techniques. This market is a candidate for penetration by the very small aperture earth station interests for teleconferencing, educational TV, medical and health diagnostics, and other public service applications as well as commercial TV. The satellite video receiver will be available in the 12 GHz band as more traffic moves to that frequency range.

4.6 PROCESSED (SLOW-SCAN) VIDEO

4.6.1 General Description and Specifications

The equipment category covered in this section is slow-scan or processed video. The normal baseband bandwidth of 4.2 MHz required for a video signal is too wide for transmission over voice bandwidth or other narrowband channels. There are many applications of video where the transmission of essentially still pictures or limited motion pictures is sufficient, but where the depth-of-field and imagery inherent in a real scene as opposed to a picture precludes flat-copy transmission. Such applications are found in educational TV, medical diagnosis, security monitoring, and business conferencing. For these applications, the use of slow-scan or reduced bandwidth video is a technically viable and cost-effective solution. Digital techniques are most often used in conjunction with slow-scan vide to encode the white-to-black scale and the scanning lines.

While slow-scan TV has been a subject of considerable research and development, only a few companies actually have equipment on the market. In addition, specialized techniques used for particular applications, such as the transmission of meteorological satellite cloud-cover pictures, amount to slow-scan or processed video. New developments in solid-state video cameras use digital or processed signal outputs for special purpose applications. These techniques and equipment are included in this discussion.

4.6.1.1 Technical Discussion

The well-known advantage of modern TV techniques is the ability to transmit signals containing moving imagery. Conventional video generates thirty highly redundant pictures every second in order to capture fully the smooth motion of a moving subject. However, there are many applications where the subject matter moves slowly, if at all, and for these applications, the transmission of a greatly reduced number of pictures per unit time allows much lower bandwidths to be used in the transmission equipment.

In the case of teleconferencing, security monitoring or medical diagnostics, the transmission of single pictures provides enormous savings in channel capacity. Equipment of the slow-scan type now on the market allows video pictures to be sent over ordinary phone lines. Indeed, most of the equipment, while not simple, is really no more than a video bandwidth compressor between a conventional TV or CCTV* camera and a coupler to a telephone line. At the other end, a bandwidth expander takes the signal from the phone coupler and displays it on a conventional TV monitor.

The compression of bandwidth is generally accomplished by stretching out the signal in time from 30 pictures per second to something like one picture in 10 seconds and sacrificing some resolution in the final reproduced image. The essential operating principles of this equipment involve stopping the motion in a normal, but slowly changing, image. This is achieved by use of a "frame grabber" which, either at preset intervals or on a signal from an operator, "freezes" a single image for transmission. The "frame grabber" does not really stop motion, however, and the subject must be essentially motionless during the 1/30th of a second in which the frame is being recorded, otherwise blurring will result at the receiving end.

The "frozen" frame in most equipment is sampled at intervals through the scan, resulting in a certain number of picture elements per scan. The grayness (black-to-white) scale of each picture element is digitized to as many as 64 gray shades depending on the resolution of the equipment. The signals thus generated frequency or amplitude modulate an audio tone and then are transmitted over a conventional phone line. If an equipment has a larger number of picture elements per scan and more gray shades per picture element, the equipment has more resolution and accurate picture reproduction. Obviously, the price of this greater resolution is the longer time required to send one picture because of the greater number of picture elements to be sent. Therefore, the number

* CCTV = Closed Circuit Television

of picture elements per TV line, the number of gray shades, and the time to transmit are interrelated and are important specifications for comparison of slow-scan TV systems. Sending end voltages and impedance and receiving end sensitivity and impedance are important interface specifications.

Analog slow-scan devices sample once per normal TV line, starting in the upper left corner of the raster and produce a vertical line from top to bottom. The analog output has a line rate equal to the field rate of the input video and the lines are constructed top to bottom. The field is constructed left to right. Output bandwidth is in the 8 KHz region with transmission time on the order of one minute or greater for one picture.

The major advantage of compressed video transmission over normal facsimile, other than speed, is the fact that the TV camera can view anything from microscipic to macroscopic, flat to three-dimensional, near or distant, and in color. Received images can be displayed on desk-top monitors or large projection viewers. Connection to remote computers for image analysis can be accomplished. Public service institutions such as governmental agencies, hospitals, universities, and research establishments are among the users. Conferencing in such areas as medical diagnostics, where X-Ray pictures may be discussed if of particular interest. Other medical uses include emergency situations, remote area consultation and diagnosis, and instruction.

4.6.1.2 Slow-scan Video Specifications.

Table 4.6-1 is a compilation of slow-scan video systems from the three major manufacturers, Colorado Video, Inc. (CVI), Robot Research and Manufacturing, Inc. and NEC. Each company makes separate transmitters and receivers and also supplies transceivers. Prices are roughly proportional to resolution in picture elements (pixels) and frame time. Table 4.6-2 presents the manufacturers' names and addresses.

Table 4.6-1

Comparison of Slow-Scan Video Systems

Vendor	Model No.	Type	Resolution (pixels)	Bandwidth	Frame Time	Grayscale	Inputs	Outputs	Price
CVI	260B	Analog Compressor	256 x 512	1 kHz	78 sec	Analog	1 V p-p 75 Ω 525/625 lines	6 V p-p white positive 600 Ω 6.6 lines/sec	$2500
CVI	262A	Analog Compressor		8 kHz	4-30 sec	Analog	1 V p-p 75 Ω 525/625 lines	0 to 4 V 600 Ω white positive	$1250
CVI	274B	Video Frame Store	256 x 512 Full Resolution	—	8.5 sec	6 bits (64 gray levels)	1 V p-p 75 Ω	16 bit digital word	$7200
CVI	275	Video Expander	256 x 512 Full Resolution	8 kHz (Option)	8.5-78 sec	6 bits	100 mV FM 600 Ω, or 2 V p-p 8 kHz, 600 Ω	Comp. Video 1 V p-p 75 Ω	$7500
CVI	280	Video Trans-ceiver	256 x 512 Full Resolution	8 kHz (Option)	75 sec	6 bits	Rcv: 100 mV FM 600 Ω Tx: 1 V p-p 75 Ω Comp. Video	Rcv: 1 V p-p 75 Ω Comp. Video Tx: 0-2 V p-p FM 600 Ω	$10,000
Robot	510	Receiver	128 x 128	Voice Band	8.5 sec	4 bits (16 gray shades)	20 mV to 1 V 1000 Ω	1.4 V p-p 75 Ω white positive	$1395
Robot	520	Trans-mitter	128 x 128	Voice Band	8.5 sec	4 bits	1.4 V p-p 75 Ω white positive	20 mV to 1 V 1000 Ω	$1545
Robot	530	Trans-ceiver	128 x 128	Voice Band	8.5 sec	4 bits	(same as for Models 510 and 520, above)		$1695
Robot	630	Trans-ceiver	256 x 256	Voice Band	35 sec	6 bits (64 gray shades)	Tx: 1.0 V p-p 1000 Ω white positive Rcv: 20 mV to 1 V, 1000 Ω	Rcv: 1.4 V p-p 75 Ω white positive Tx: 1.9 V p-p 900 Ω	$4890

Table 4.6-1 (cont'd)

Comparison of Slow-Scan Video Systems

Vendor	Model No.	Type	Resolution (pixels)	Bandwidth	Frame Time	Grayscale	Inputs	Outputs	Price
NEC	TVS-754TR	Transceiver	280 TV lines		30 sec	-	Std.TV signal inputs	Std. TV signal outputs	$17,000
NEC	TVS-754T	Transmitter	"		"	-	"	"	$14,900
NEC	TVS-754R	Receiver	"		"	-	"	"	$12,770
NEC	TVS-751TR (Color)	Transceiver	-		1-600 sec	-	Std. Color TV signal inputs	Std. Color TV signal outputs	$19,000
NEC	TVS-751T (Color)	Transmitter	-			-	"	"	$16,720
NEC	TVS-751R (Color)	Receiver	-			-	"	"	$13,680

Table 4.6-2

Slow-Scan and Phone Line Video Suppliers

Colorado Video, Inc. Box 928 Boulder, Colorado 80306	(303) 444-3972
Robot Research, Inc. 7591 Convoy Ct. San Diego, CA 92111	(714) 279-9430
Nippon Electric Co., Ltd. NEC America 130 Martin Lane Elk Grove Village, IL 60007	(312) 640-3792

4.6.2 Future Trends

Slow-scan video, in practice, is a relatively new technique itself. It can be expected to find increasing use in teleconferencing, medical diagnostics, educational TV. Advances in display technology and imaging techniques may contribute to the increasing use of slow-scan video by reducing the weight, bulk, and power requirements of video equipment, thus making it feasible for remote area transmission and reception.

4.7 SPECIAL PURPOSE PROCESSED VIDEO EQUIPMENT

4.7.1 General Description and Specifications

There are some types of video equipment which may not be thought of as such, yet because of their applications these equipments are, in effect, processed video equipments. A quite important application of processed video equipment of some interest to the public service user is that used with the Geosynchronous Orbiting Environmental Satellites (GOES), and Synchronous Meteorological Satellites (SMS).

There are a number of satellites presently in orbit which have the purpose of taking visible and infrared pictures of the earth and its cloud cover. These pictures can be used to forecast precipitation and temperatures as well as for non-meteorological purposes. The cameras and radiometers which scan the earth's surface from the satellite generate pictures on a line-by-line basis, just as in other video applications. These pictures are transmitted to a processing station on the earth's surface where the scan time of the video signals is slowed down, or stretched. The stretched video signals are then transmitted back thru the satellite for retransmission to other user terminals on earth. Any user in any country that needs or wants these stretched video signals can install the proper receiving and processing equipment and can print out the satellite photos of the earth's surface. In addition, in the U.S., interested users can install conditioned telephone lines and the required terminal equipment and print the pictures out on special facsimile equipment. This is possible because the stretched video signals have been slowed down to a point where they can be transmitted over telephone wires.

It is beyond the scope of this study to go into the details of operation of the various synchronous meteorological satellite systems. However, we will present some of the terminus equipment specifications and vendors.

The transmissions of interest to the public service user are the stretched VISSR (Visible and Infrared Spin Scan Radiometer) data, which contains the satellite photos of the earth's surface; the DCP (Data Collection Platform) Reports, which contain information on stream levels, snow depth, etc. collected from small transducers spread over the earth's surface and transmitted thru the satellite; and WEFAX (Weather Facsimile) charts, which are weather charts and maps sent out from the Weather Service by facsimile over the satellite.

4.7.1.1 GOES/SMS Receiving Systems.

Following are the general system specifications for an entire receiving system that can receive GOES/SMS transmissions, including stretched VISSR, WEFAX, and DCP reports:

Antenna Diameter	5 meter
Downlink Frequency	1690 MHz
Modulation	Bi-PSK
System Noise Temperature	300°K
BER (Bit Error Rate)	1×10^{-5}
Carrier-to-Noise Ratio	12 dB
Bandwidth	8 MHz

The following vendors are offering entire GOES/SMS receiving systems capable of receiving the stretched VISSR data and displaying on hard copy the satellite pictures, receiving and processing the Data Collection Platform Reports, and printing on hard copy the WEFAX reports. The systems use sophisticated receivers, demodulators, bit and frame synchronizers, computer interfaces, laser facsimile recorders, and WEFAX facsimile recorders. Systems market at about the $160,000 price level. Receivers alone capable of demodulating the various signals by using replaceable plug-in modules market at about $20,000-$25,000.

Table 4.7-1

GOES/SMS Receiving System Suppliers

Signetics International, Inc. P.O. Box E Boulder, Colorado 80306	(303) 447-2341
EMR Division of Schlumberger Box 3041 Sarasota, Florida 33578	(813) 371-0811
Harris Corporation Electronics Systems Division P.O. Box 37 Melbourne, Florida 32901	(305) 727-4000
Microdyne Corporation P.O. Box 1527 Rockville, MD. 20850 (Receivers only)	(301) 762-8500

4.7.1.2 GOES and GOES/TAP Systems

The National Environmental Satellite Service makes available thru five outlets in the nation the sectorized satellite pictures from the GOES/SMS satellites. These services are available to any user for the cost of installing and leasing a conditioned telephone line and the proper receiving equipment. For more information, the reader is referred to the GOES/SMS User's Guide, published by NOAA and NASA. The following vendors have the receiving/facsimile equipment on the market. Units can be purchased or leased.

Table 4.7-2

GOES and GOES/TAP Receiving Systems

Vendor	Model	Purchase	Lease
Muirhead, Inc. 1101 Bristol Rd. Mountainside, N.J. 07092 (201) 233-6010	M-136-H/5 Electrostatic for GOES/WEFAX	$5250	#225-275/mo. depending on service
	M-136-J/3 for WEFAX	$6300	$235-285/mo. depending on service
	M-300 Laser Recorder for GOES/WEFAX/ TIROS/N	$15000	$1000-1500 depending on service
Alden Electronic & Impulse Recording Co., Inc. Alden Research Center Westborough, MA. 01581 (617) 366-8851	Alden 1800 Model 9271 D/H/AEC	$4500	$224-349/mo. for 30-120 charts/day
EMR Division of Schlunberger Box 3041 Sarasota, Fla. 33578 (813) 371-0811	EMR 816-02 Laser Facsimile Recorder for WEFAX (Harris 850 Laserfax)	$18000	-
Harris Corp. Electronic Systems Div. P.O. Box 37 Melbourne, Florida 32901 (305) 727-4000	850 Laserfax	$18000	-
Datalog Div. Litton Industries 1770 Walt Whitman Road Melville, Long Island, N.Y. (516) 694-8300	-	-	-

4.7.1.3 Scan Converters.

Scan converters are laboratory devices which can be used to store, speed up, slow down, add, subtract, or divide sets of analog data in various experimental situations. They can be used with analog or analytical instruments such as lock-in amplifiers, electrometers, polarographic analyzers, or spectrometers. In these situations, they can be used for source compensation or background and baseline correction of analog data that may be displayed on a CRT or recorded on paper In effect this device accepts as an input x-y data at one scan rate and reads it out at another scan rate by sampling the input scanning lines. Shades of gray are, as in other equipment of this type, a function of the number of bits resolution in the sampling scheme. Princeton Applied Research Corporation, (609) 452-2111, P.O. Box 2565 Princeton, New Jersey 08540 supplies the device described below.

Table 4.7-3

Scan Converter Specifications

Scan Recorder: Model 4101

Memory	1024 points
Y-input	
Resolution	10 bits
Sensitivity	1100 mV to ±10 V
Impedance	1 MΩ shunted by 20 pF
X-input	
Rate of Sweep	50 μsec to 50 sec per point
Scope Output (Y-axis)	70 Hz for 512 points
	37 Hz for 1024 points
	±0.5 VDC_{max} @ 600 Ω
Scope Output (X-axis)	70 Hz for 512 points
	37 Hz for 1024 points
	0 to +1 V ramp @ 600 Ω
Power	105-125 or 210-250 VAC, 50-60 Hz
	45 W
Weight	15 lbs.
Price	$2750.00

4.7.2 Future Trends

Four of the five GOES/SMS satellites planned are now in orbit, so the next few years in this technology will be marked by increasing use of the data, new methods of data processing, and new applications for the output information. An increasing number of agencies and industries will be using the data output, and some of these will see fit to install small earth stations for direct reception of the data, rather than receiving it over telephone lines. Lower costs for some of the receiving and data processing equipment will follow developments in these fields.

5. MULTIPLE ACCESS EQUIPMENT

5.1 FDM/FDMA EQUIPMENT.

Multiple access is the term used to describe the manner in which several users of a communication system may simultaneously use a common communications facility. In satellite communication systems multiple access is the technique by which several earth stations can simultaneously access a common satellite repeater.

Figure 1 shows the various pieces of equipment which make up the uplink for a typical earth station (or line-of-sight microwave). The first piece of equipment in this link is the multiplex gear the input to which may be one or several baseband (voice, data, or video) channels. The output of the multiplexer will be a composite signal made up of one, or many, baseband channels. This composite signal will be the input to a modulator. The output of the modulator may be either a frequency modulated signal or a digitally modulated signal using digital modulation techniques such as FSK (frequency shift keying), PSK (phase shift keying), or QPSK (quadriphase shift keying). This modulated signal is next mixed with an IF signal, typically at 70 MHz, and then upconverted to the appropriate RF frequency (such as 6 GHz or 14 GHz satellite uplink frequency).

5.2 GENERAL DISCUSSION.

One form of multiple access is obtained by dividing the available transmission band (5925 MHz-6425 MHz in a 4/6 GHz satellite system) into frequency slots, and assigning to each earth station a carrier frequency in a unique frequency slot. This form of multiple access is called frequency division multiple access (FDMA). Instead of preassigning carriers to earth stations, it is also possible to assign carriers to an earth station only upon demand. This form of multiple access is termed demand assignment multiple access (DAMA) in which a pool of carrier frequencies are defined within the transmission band and assigned to users randomly only when required. For a DAMA system, some additional control equipment is required to keep track of frequency assignments.

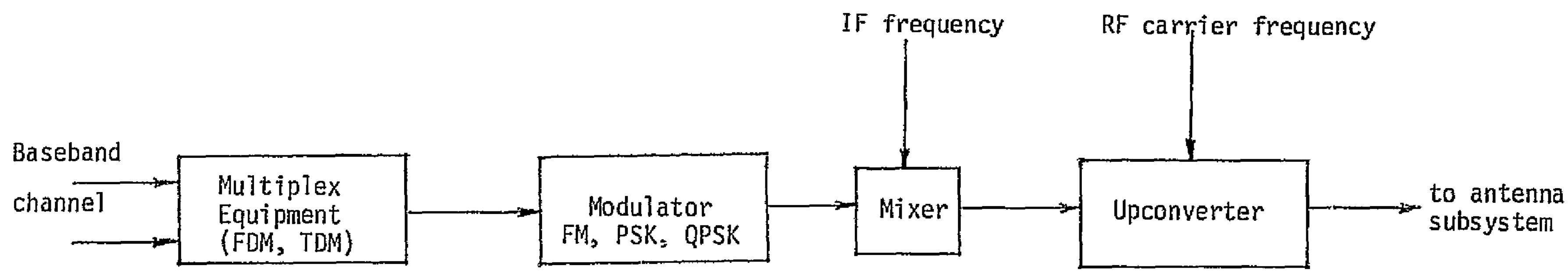

Fig. 5.1 — Typical uplink equipment in a satellite earth station or line-of-sight microwave.

Another form of multiple access is obtained when each earth station is assigned a unique time slot for transmission. This form of multiple access is known as time division multiple access (TDMA), and utilizes a single carrier frequency (usually at the center of the available band) common to all earth stations. The modulated IF signal, (Figure 1), whether digital or analog, is upconverted to this carrier frequency and transmitted as a burst of information in the allotted time slot. Usually TDMA signals are QPSK modulated while FDMA signals are FM modulated. With a TDMA system additional complexity is required at the earth station for synchronizing and formatting the burst information.

A system in which more than one baseband channel is first frequency division multiplexed (FDM) and then frequency modulated (FM) is called an FDM/FM system. If the multiple access technique used is FDMA, this FDM/FM signal will be upconverted to an assigned carrier frequency. The whole multiple access system is then called a FDM/FM/FDMA system. If there is no previous multiplexing, but a single baseband channel is frequency modulated and then upconverted to an assigned carrier frequency, the system is called SCPC/FM/FDMA, where SCPC stands for single channel per carrier. If the carrier frequencies in such a system are assigned to individual earth stations upon demand then the system is a SCPC/FM/FDMA/DAMA system. Usually a demand assigned multiple access system is most efficient when used with single channel per carrier modulation.

In a similar manner, we can define TDM/QPSK/TDMA or TDM/QPSK/FDMA systems. In these systems many baseband channels are time-division multiplexed (TDM) before modulation. Since the input is a digital bit stream the modulation technique is either FSK or some form of PSK (in this example quadriphase shift keying is used). The modulated signal is next upconverted to a carrier frequency and in the case of TDMA transmitted in burst format in the allotted time slot of each frame. Here, again, we may have systems such as SCPC/QPSK/TDMA or DAMA.

In this portion of the study we will discuss only that portion of the total system which comes before the modulator, (i.e., the multiplex gear), since the output of the multiplexer is the final waveform which must be transmitted over the communication channel. In the following sections we will discuss in order the specifications and models available for frequency division multiplex (FDM) equipment, time division multiplex (TDM) equipment and SCPC gear.

5.3 FREQUENCY DIVISION MULTIPLEXING.

Frequency division multiplexing is one method of assembling telephone channels into a single baseband system per RF channel. Thus many smaller bandwidth signals are stacked together to form a larger baseband bandwidth signal before transmission over a single RF channel. Frequency division multiplex has been traditionally employed in terrestrial telecommunication systems which employ wideband transmission facilities such as co-axial cable or microwave radio. The baseband of a microwave link consists essentially of a number of multiplexed telephone channels or video or data. Capacities vary up to 1860 telephone channels with some 2700 channel systems. Capacities of 600, 960, 1260 or 1860 channels are common.

The modulation plan which describes the baseband layout of the multiplexed signals has been standardized by CCITT[1] to allow large telephone networks both national and international to interconnect. The standard CCITT group consists of 12 voice channels in the frequency spectrum between 60-108 KHz. This group is formed by using single side-band suppressed carrier modulation (SSBSC) techniques to translate the lower sideband of each 4 KHz voice channel to a unique position within the 60-108 KHz band. The CCITT recommended carrier frequencies which are modulated by each voice channel vary from 64 KHz to 108 KHz separated by 4 KHz.

A supergroup contains five standard CCITT groups equivalent to 60 voice channels. The standard supergroup is formed by translating five standard base groups to the frequency band between 312-552 KHz. This translation is carried out by mixing each basegroup with a carrier frequency in the range 420 KHz to 612 KHz separated by 48 KHz.

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(1) International Consultive Committee for Telephone and Telegraph, organized under the auspices of the International Telecommunications Union (ITU), Geneva.

The basic mastergroup contains five supergroups or 300 voice channels. It occupies the spectrum from 812 - 2044 KHz and is formed by translating the five standard supergroups, each occupying a 312 - 552 KHz band by mixing with carrier frequencies between 1364 KHz to 2356 KHz separated by 248 KHz.

The band of frequencies which are output from the multiplexer is called the line frequency, since it is now ready for transmission on the selected transmission medium.

The North American Bell System uses L carrier to denote their long-haul SSB carrier system. The modulation plan for L carrier is essentially the same as the CCITT recommended modulation plan. The basic mastergroup however consists of 600 VF channels (i.e., 10 standard supergroups) in the frequency band from 60 - 2788 KHz for the L600 system and 564 - 3064 KHz for the U600 system.

Other line frequency configurations are available for transmission of groups of voice channels over different types of medium such as open wire or cable. Some examples of these are the twelve-channel open wire carrier, the North American K carrier system over non-loaded cable pairs, N carrier system for transmission over non-loaded cable pairs, carrier transmission on star or quad type cables, coaxial cable carrier transmission systems and subscriber carrier - station carrier systems.

5.3.1 Performance Characteristics of an FDM System

5.3.1.1 Loading

For a multi-channel system, CCITT recommends for the average power of the composite signal

$$P_{av} = -15 + 10 \log N \quad \text{for } N > 240$$
$$P_{av} = -1 + 4 \log N \quad \text{for } 12 \leq N < 240$$

where N = number of voice channels.

The average power per voice channel allowed by the CCITT is -15 dBm0. This assumes a standard deviation of 5.8 dB and an activity factor of 0.25. Activity factor is the proportion of time that the rectified speech envelope exceeds some threshold.

Certain other signals transmitted over the multi-channel system such as telegraph tone, signaling tones, pilot tones and data signals are transmitted continuously at constant amplitude. These signals are characterized by an activity factor of 1. For typical constant amplitude signals traditional transmit levels are as follows:

Data -13 dm0
Signaling, tone on when channel is idle -20 dBm
Composite telegraph -8.7 dBm0

5.3.1.2 Pilot Tones

Pilot tones in FDM equipment have essentially two purposes:

- Control of level
- Frequency synchronization

Pilot frequencies are part of the transmitted spectrum but should not interfere with voice channel operations. CCITT has assigned the following as group regulation pilots:

84.080 KHz (at a level of -20 dBm0)
84.140 KHz (at a level of -25 dBm0)
104.080 KHz (at a level of -20 dBm0)

For CCITT group pilots, the maximum level of interference permissible in the voice channel is -73 dBm0p.

Other CCITT pilot tone frequencies are as follows:

Basic Supergroup: 411.860 KHz (at a level of -25 dBm0)
411.920 KHz (at a level of -20 dBm0)
547.920 KHz (at a level of -20 dBm0)
Basic Mastergroup 1552 KHz (at a level of -20 dBm0)

The operating range of level control equipment activated by pilot tones is usually about ± 4 or 5 dB.

A frequency synchronizing pilot is used to maintain accuracy of carrier frequencies. CCITT does not recommend a frequency synchronizing pilot. The Defense Communications Agency recommends 96 kHz as a frequency synchronizing pilot on group 5 of supergroup 1. Other systems use 60 kHz at a -16 dBm0 transmit level. Frequency synchronizing pilots are not standard design features owing to the improved stabilities now available in master oscillators.

Master frequency sources should have sufficient stability and accuracy to meet the following:

Channel carrier frequency	$\pm 10^{-6}$
Group and Supergroup carrier frequencies	$\pm 10^{-7}$
Mastergroup, for 12 MHz line frequency	$\pm 5 \times 10^{-8}$
for 60 MHz (above 12 MHz)	$\pm 10^{-8}$

In modern FDM equipment a redundant master frequency generator serves as the prime frequency source from which all carrier frequencies are derived. On the transmit side the frequency synchronizing pilot is derived from this source. Some equipment manufacturers now provide a direct to line modulation scheme in which a voice channel can be translated anywhere within the CCITT line spectrum using programmable crystal controlled oscillators for individual voice channels.

5.3.1.3 Noise Measurements

The CCITT guide for allocating mean psophometric noise power produced by all multiplex equipment (not to exceed 2500 pW at a zero relative level point) is the following:

for 1 pair of channel modulators	200 to 400 pW
for 1 pair of group modulators	60 to 100 pW
for 1 pair of supergroup modulators	60 to 100 pW

Often these target figures can be improved on considerably. The total allowable noise contributed (2500 pW) limits the number of times a baseband system can be demodulated to voice along a transmission link.

5.3.1.4 Distortion

The CCITT recommended limits for attenuation distortion of a voice channel are available in CCITT Rec.G.232A. The CCITT recommended guideline on group delay for a pair of channel modulators is as follows:

300 Hz, 4.2 ms; 400 Hz, 2.9 ms; 2000 Hz, 1.2 ms;

3000 Hz, 1.8 ms and 3400 Hz, 3.4 ms (reference 800 Hz).

Table 1 compares some basic CCITT system parameters with AT&T's L carrier.

5.3.2 FDM Equipment Manufacturers and Models

Table 2 is a list of some of the equipment models available. Besides Western Electric, GTE Lenkurt and Farinon are the largest suppliers of multiplex equipment. It is difficult to give a definitive price for FDM equipment since the equipment configuration varies according to specific applications. Most manufacturers have a catalog with part numbers for the various pieces of equipment which are put together to form a multiplex assembly. Each part number has an associated price. Based on customer requirements for the number of channels, location of the multiplex site, power, reliability, number of hops and channel drops and insertion, each multiplex assembly is configured differently and the cost of the various parts required is totaled to obtain the assembly cost. In Table 2 we have attempted to give the cost of certain key parts such as channel equipment, group equipment and frequency generators. These should not be used to compare different vendor models. It is simpler to price out direct-to-line equipment since each channel is a complete unit by itself with an associated carrier frequency generator and does not normally share common equipment with other channels. Direct-to-line equipment is more flexible especially when a number of channel inserts and drops are required, since a channel can be inserted or dropped from anywhere within the line spectrum, without requiring the demodulation of the whole line spectrum to baseband. But for high density backbone routes requiring higher performance and reliability, it is more economical to share equipment such as the frequency generator, group and supergroup modulation equipment between many channels since the per channel cost can then be greatly reduced. It is also important to watch out for system compatibility since some models, like the GTE 36A and Farinon LD-G, can interface only with themselves. These equipment types normally use carrier leak signaling instead of the out-of-band signaling (CCITT recommended 3825 Hz) used on high density multiplex routes. For specific applications, systems should be separately priced out by contacting appropriate

Table 5.3-1

L-Carrier and CCITT Comparison Table

Item	AT&T L-Carrier	CCITT
Level		
Group		
Transmit	-42 dBm	-37 dBm
Receive	- 5 dBm	- 8 dBm
Supergroup		
Transmit	-25 dBm	-35 dBm
Receive	-28 dBm	-30 dBm
Impedance		
Group	130 Ω balanced	75 Ω unbalanced
Supergroup	75 Ω unbalanced	75 Ω unbalanced
VF channel	200-3350 Hz	300-3400 Hz
Response	+1.0 to -1.0 dB	+0.9 to -3.5 dB
Channel carrier		
Levels	0 dBM	Not specified
Impedances	130 Ω balanced	Not specified
Signaling	2600 Hz in band	3825 Hz* out of band
Group pilot		
Frequencies	92 or 104.08 kHz	84.08 kHz
Relative levels	-20 dBm0	-20 dBm0
Supergroup carrier		
Levels	+19.0 dBm per mod or demod	Not specified
Impedances	75 Ω unbalanced	Not specified
Supergroup pilot frequency	315.92 kHz	411.92 kHz
Relative supergroup pilot levels	-20 dBm0	-20 dBm0
Frequency synchronization	Yes, 64 kHz	Not specified
Line pilot frequency	64 kHz	60/308 kHz
Relative line pilot level	-14 dBm0	-10 dBm0
Regulation		
Group	Yes	Yes
Supergroup	Yes	Yes

*Recommended, but depends on system. (Source: R.L. Freeman, Telecommunication Reansmission Handbook, New York: John Wiley & Sons, 1975.)

Table 5.3-2

Frequency Division Multiplex Equipment

MANUFACTURER & MODEL NUMBER	NUMBER OF CHANNELS	FREQUENCY MODULATION PLAN	COST*
GTE Lenkurt 36A2 multiplex system	1-614 occupying the frequency range between 4 and 2540 kHz	Direct 12-line modulation to the standard CCITT* 600 channel line spectrum plus Group A and two channels between 4 kHz and 12 kHz. Uses carrier leak signaling. Can only interface with itself.	12-channel assembly, fully equipped: $918; 60-channel assembly, fully equipped: $3289; 120-channel assembly, fully equipped: $5665. 12-channel rack: $120; each channel unit: $380; crystal oscillator for each channel unit: $40; transformer panel for each group assembly plug-in: $160.
GTE Lenkurt 46A3 multiplex system (Type 46A6 is available to meet Bell System requirements)	1-2400 occupying the frequency range between 60 and 11,404 kHz	Available using either direct to line modulation to place 12, 60, 72, or 132 channels directly onto line, or directly formed supergroup modulation to establish standard 60-channel supergroup (312-552 kHz) or conventional modulation. Compatible with GTE Lenkurt 46A, Western Electric A type channels and L-Carrier and CCITT system.	For a conventional channel equipment arrangement, 180-channel equipment assembly: $6654; common equipment, $773; 12-channel group: $2636 each. Additional racks will be required for group and supergroup and mastergroup equipment. A 60-channel group assembly including common equipment and group carrier generating equipment will cost approximately $4000.

Table 5.3-2 (continued)

MANUFACTURER & MODEL NUMBER	NUMBER OF CHANNELS	FREQUENCY MODULATION PLAN	COST*
GTE Lenkurt 46B Cable Carrier	2-24 channels on two cable pairs in the 36-132 kHz (low group), 172-268 kHz (high group) frequency range	Used on intertoll and toll connecting trunks. Single sideband suppressed carrier modulation. Compatible with Western Electric model N3 carrier system. Can be used on cable routes up to 200 miles in length.	$21,380 for a 24-channel assembly plus additional for mounting, wiring, and signaling.
GTE Lenkurt 47 A/N1 and 47A/N2 cable carrier systems	4-12 channels on 1200 cable pairs in the 36-140 kHz (low group), 164-268 kHz (high group) frequency range	Exchange and toll connecting trunk carrier system, compatible with Western Electric N1 or N2 carrier systems. Designed for cable routes up to 200 miles in length.	12-channel system: $5195
GTE Lenkurt Subscriber Carrier systems 82-A, 82-B and 83-A, 84-A	Types 82A, 82B provide 1-6 channels on a single wire pair in the frequency range 72-140 kHz (C.O. to station) and 8-56 kHz (station to C.O.). Types 83 A and 84A provide 1 channel plus the physical circuit on a single pair. Frequency allocation is 76 kHz (C.O. to station) and 28 kHz (station to C.O.)	Operate on cable and open wire. Frequency plan meets industry standard for station carrier equipment. Maximum system length is 20 miles of 19 gauge cable for 82A, 28 miles for 82B, 7 miles for 83A, and 7.5 miles for 84A.	

Table 5.3-2 (continued)

MANUFACTURER & MODEL NUMBER	NUMBER OF CHANNELS	FREQUENCY MODULATION PLAN	COST*
Farinon DL-1 multiplex	Can provide up to 1860 channels directly in the frequency range from 12 to 2044 kHz	Direct to line modulation onto the radio baseband. Using three modulation steps, groups of six channels in a 10,688 to 10,712 kHz basic subgroup are modulated directly onto channels 1 to 6 or 7 to 12 in any CCITT group from Group A (12-60 kHz) through Supergroup 8 (2044 kHz). Uses out of band signaling at 3825 Hz. Compatible end to end with CCITT multiplexer terminals.	Including common equipment, for first six channels: $5222; for next six channels: $3585; and $3585 for next six channels.
Farinon LD-G multiplexer	Up to 614 voice or data channels in a 4 to 2540 kHz baseband	Uses a three-step modulation plan to modulate six channel groups in a (12 kHz to 36 kHz) basic subgroup onto CCITT recommended allocation from 12 to 2540 kHz as well as existing LD equipment. Carrier leak signaling. Compatible only with itself.	With 24 volts power, 12 channels fully wired: $6564; 24 channels fully wired: $12,844. Each channel less, delete $441.
Farinon FC-600 multiplex	Up to 600 channels in the frequency range from 60 kHz to 2540 kHz	The modulation plan provides 1-600 channels in supergroups one through ten. Supergroup 1A (12-252 kHz) can also be provided. Optional carriers for supergroups 9 and 10 provide compatibility with either the CCITT modulation plan or the Western Electric "L" system.	Budgetary estimate of $825 each channel end

Table 5.3-2 (continued)

MANUFACTURER & MODEL NUMBER	NUMBER OF CHANNELS	FREQUENCY MODULATION PLAN	COST*
Granger 7300 multiplex	Up to 614 channels in the 4 to 2540 kHz frequency band	A direct to line modulation scheme translates a voice channel anywhere within the CCITT line spectrum from 12 to 2540 kHz plus two additional channels between 4 and 12 kHz. Works end to end with CCITT multiplexers. Uses 3825 Hz out of band signaling.	12-channel wired shelf: \$374; per channel modem: \$481; set of VF cables per shelf: \$75; one synchronization unit: \$540; 48 volt converter (optional) which can power up to 24 channels: \$288.
Coastcom SBC 700 multiplex	14 lower sideband channels between 4 kHz and 60 kHz, and 12 upper sideband channels between 12 kHz and 60 kHz.	CCITT compatible channels in simplex or duplex mode within the CCITT Group A frequency plan. Transmit and receive portions consist of different plug-in units. Uses carrier leak signaling.	
Comtech TCPC (two channels per carrier) system	1 to 24 telephony voice channels per carrier for satellite transmission; RF carrier capacity up to 400 TCPC carriers (800 channels)	Data is transmitted in FSK format, while audio information is frequency division multi-plexed or time-plexed. Channel bandwidth: 3.1 kHz standard; 5 kHz, 8 kHz, 15 kHz options. System comes with all components for transmission and reception via satellite.	

Table 5.3-2 (continued)

MANUFACTURER & MODEL NUMBER	NUMBER OF CHANNELS	FREQUENCY MODULATION PLAN	COST*
Rockwell-Collins MX-108	System configurations from 12 to as many as 2700 channels are available.	Available in a direct to line configuration for placing 12 to 600 channels directly onto the high frequency line. May operate in Supergroup A or any supergroup between 1 through 10. Also available in a directly formed supergroup in which 60 voice channels are directly translated to the 312 to 552 kHz spectrum. Conventional mudluation schemes can also be applied. Compatible with both CCITT and Western Electric.	
Karkar KM-960	Up to 2700 channels	Compatible with the L system and CCITT modulation plans. Meets DCA requirements. A two-step modulation plan first modulates the VF onto 128-132 kHz before translation to the CCITT basic group between 60-108 kHz.	Average price estimate: $300/channel for a 600-channel system.

Table 5.3-2 (continued)

MANUFACTURER & MODEL NUMBER	NUMBER OF CHANNELS	FREQUENCY MODULATION PLAN	COST*
Karkar KM-12/24	Capable of transmitting up to 24 speech channels in the frequency band from 6 to 108 kHz.	Can interface with different multiplex systems, with different frequency allocations, pilots, impedances and levels. Different system requirements are selected by switches in the group modem. A two-step modulation plan first forms a pre-group from 128 to 132 kHz before translation to the 60 to 108 kHz CCITT basic group. Made to interconnect with existing European systems.	$1000/channel end
Cardion Electronics Series 8000 Multiplex	Capable of transmitting 12,24 or 36 channels in the 12-156 KHz band.	Two 6 channel pregroups each occupying the band from 4-28 KHz are used to form the 12 channel CCITT groups A,B or C by frequency translations.	

* CCITT stands for the International Consultive Committee for Telephone and Telegraph.

Note: The costs quoted here are estimates given by vendors for certain individual equipment parts. These should not be used for comparative purposes. A budgetary estimate must be obtained from the vendor once a complete system is specified.

vendors. Table 3 is a list of some of the FDM equipment vendors. Tables 4 and 5 are two typical specification sheets for the GTE Lenkurt direct-to-line type 36A multiplexer and the GTE Lenkurt 46A multiplex system, respectively.

5.4 TIME DIVISION MULTIPLEXING.

Time division multiplexing is usually obtained by interleaving the bit streams from several low data rate channels to form one high-speed data stream for transmission over a single facility. In this section we will describe only that equipment which multiplexes more than one voice channel onto a single wideband transmission facility. We will not discuss the wide variety of multiplexing gear that is used for multiplexing low speed data channels in computer communication networks.

A typical time division multiplex system consists of a sampler and a quantizer and encoder at the transmitting end and a decoder and sampler at the receiving end. Several speech waveforms are sampled at a rate equal to, or higher than, the Nyquist rate (8000 samples/second for a speech signal) and these samples are interleaved to form a pulse amplitude modulated (PAM) signal. This signal is next converted into a pulse code modulated (PCM) signal by assigning a binary code* to each discrete amplitude level in the PAM signal. Some of the PCM systems in use today are the AT&T D1 system, CEPT (Conference European des Poste et Telecommunications) and the AT&T D2 system. The AT&T D1 system consists of 24 voice channels which are sampled at the rate of 8000 samples/sec. These samples are then interleaved and coded using a seven level code (7 bits/sample). To each seven bits representing a coded sample value one bit is added for signaling. To the full sequence one bit is added for framing. Thus a single frame of 24 samples contains:

$$(7+1) \times 24+1 = 193 \text{ bits}$$

* A binary code is a unique combination ·'0's and '1's representing a distinct signal level in the PAM sign.

Table 5.4-1

List of FDM Manufacturers

GTE Lenkurt 1105 Old County Road San Carlos, CA 94070	(415) 595-3000
Farinon Electric 1691 Bayport Avenue San Carlos, CA 94070	(415) 592-4120
Western Electric Company	(Call local telephone company representative)
Granger Associates 3101 Scott Boulevard Santa Clara, CA 95051	(408) 985-7000
Coastcom 2346 Stanwell Drive Concord, CA 94520	(415) 825-7500
Comtech Laboratories 135 Engineers Road Smithtown, NY 11787	(516) 231-5454
Rockwell-Collins Division P.O. Box 10462 Dallas, TX 75207	(214) 996-5899
Karkar Electronics Inc. 245 - 11th Street San Francisco, CA 94103	(415) 552-1247
Motorola Communications & Electronics, Inc. Dept. G 1301 E. Algonquin Road Schaumbrug, IL 60196	(312) 397-1000
Cardicn Electronics Communications Department Woodbury, NY 11797	(516) 921-7300

Table 5.4-2

Technical Summary for the GTE Lenkurt 36A2 Radio Multiplexer

General			
System Designation		36A2 Radio Multiplex System	
Multiplexing		Frequency Division Multiplex (FDM)	
Modulation		Single sideband, suppressed carrier (SSBSC) Carrier injection for signaling and synchronization	
Channel Capacity		1 to 614	
Frequency Plan		12 kHz to 2540 kHz (CCITT Supergroups 1 through 10) 4 kHz to 12 kHz (Auxiliary channels)	
HF or Baseband Interface			
Line Frequency		4 kHz to 2540 kHz	
Impedance		75 ohms, unbalanced 124 ohms, balanced	
Return Loss	12 kHz to 2540 kHz 4 kHz to 12 kHz	≥23 dB ≥20 dB	
Line Levels 1 to 60 Channels	Transmit	−15 dBm to −46 dBm, adjustable 1-dB steps	
	Receive (Standard Level)	−6 dBm to −37 dBm, adjustable 1-dB steps	
	Receive (Low Level)	−14 dBm to −45 dBm, adjustable 1-dB steps	
61 to 614 Channels	Transmit and Receive	Levels reduced by 3.2 dB for each 75-ohm or 3.4 dB for each 124-ohm hybrid insertion loss (figure 3-9)	
Carrier Levels (Transmit)	Channel Idle Channel Busy	<−50 dBm0 −18 dBm0 ±1 dB	
VF Interface			
VF Frequency		0 to 4 kHz	
Impedance	Four-Wire (3612A) Two-Wire (3614B)	600 ohms, balanced 600 ohms, balanced +2.15 μF	
Return Loss Four-Wire (3612A)	Transmit Receive	≥23 dB ≥26 dB	
Two-Wire (3614B)	Echo Return Loss	≥25 dB	
Test Tone Levels Four-Wire (3612A)	Transmit (Fixed) Receive	−16 dBm 0 to +10 dBm (adjustable) +7 dBm (nominal)	
Two-Wire (3614B)	Transmit Receive	+4.7 to −11.8 dBm adjustable in 0.1-dB steps +2.8 to −13.7 dBm adjustable in 0.1-dB steps	
Longitudinal Balance (IEEE) (300-3400 Hz)	Four-Wire Two-Wire	≥70 dB ≥60 dB	
Frequency Response (Gain relative to 1000 Hz)	Four-Wire 600 to 2400 Hz 400 to 3000 Hz 300 to 3400 Hz	 ±0.85 dB +0.85 to −1.5 dB +0.85 to −3.0 dB	
Envelope Delay Distortion (Relative to minimum delay)		3612A	3616A
	1000 to 2600 Hz	<325 microseconds	<125 microseconds
	800 to 2800 Hz	<600 microseconds	<225 microseconds
	600 to 3200 Hz	<1000 microseconds	<375 microseconds
	500 to 3300 Hz	<1500 microseconds	<625 microseconds
Absolute Delay	2.0 kHz	1050 microseconds	520 microseconds
Total Harmonic Distortion		≤−40 dB, (1%)	
VF Level Stability	1 Hour 3 Months	±0.25 dB ±1.0 dB	
Limiting		+3.7 dBm0 output minimum, (input level of +4.0 dBm0) +8.0 dBm0 output maximum, (input level of +20 dBm0)	

Table 5.4-2 (continued)

Crosstalk		70 dB min. intelligible crosstalk coupling loss (measured between any channels within the same shelf with a 0-dBm0, 1-kHz tone in disturbing channel) 61 dB min. unintelligible crosstalk coupling loss (measured on either adjacent channel to the disturbing channel with 0 dBm0, transmitter weighted noise spectrum applied, C-message weighting)	
Sidetone		<35 dB, 300 Hz to 3400 Hz (measured at vf receive with 0-dBm0 tone applied at the vf transmit, hf transmit and receive terminated)	
Noise (HF Receive at −45 dBm)		3612A	3616A
Idle		<18 dBrnC0, 52.5 pW	<15 dBrnC0, 33 pW
Loaded per CCITT Loading (−15 dBm0/channel)	60 Channels	<18 dBrnC0, 52.5 pW	<17 dBrnC0, 42 pW
	120 Channels	<19 dBrnC0, 66 pW	<18 dBrnC0, 52.5 pW
	600 Channels	<20 dBrnC0, 83 pW	<19 dBrnC0, 66 pW
Loaded per 36A2 Loading (−8 dBm0/channel)	60 Channels	<20 dBrnC0, 83 pW	<20 dBrnC0, 83 pW
	120 Channels	<21 dBrnC0, 105 pW	<21 dBrnC0, 105 pW
	600 Channels	<27 dBrnC0, 417 pW	<27 dBrnC0, 417 pW
E&M Signaling HF Line Level Variation	% Break	Rate	Distortion
±3 dB	58	14 pps	3%
			Maximum Distortion
±3 dB	40 to 80	8 to 14 pps	5%
Frequency Stability		Synchronized end-to-end, off-hook (Channel unit frequency translation error, vf to hf, ≤60 Hz)	
Phase Jitter (Back-to-back terminals)		3612A ≤3° peak-to-peak	3616A ≤0.2° peak-to-peak
Alarms (1 Form C Rating)		Contact.Rating 1.0 A at −24 Vdc 0.5 A at 120 Vac	
Power Requirements			
Voltage	Nominal	Maximum Range	
	−24 Vdc	−22 Vdc to −28 Vdc	
	−48 Vdc	−42 Vdc to −56 Vdc	
Supply Noise	Maximum Ripple 0 to 5 kHz (Unweighted)	300 mV, rms	
Current Drain		−24 Vdc	−48 Vdc
3612A Channel Unit		120 mA	80 mA
E Lead Current Capacity		1.0 A	1.0 A
M Lead Current Drain		1.0 mA	2.8 mA
3616A Translator Unit		100 mA	60 mA
1103A/B Loop Originating Adapter Unit		— —	60 mA (idle)
		— —	75 mA (busy)
1104A/B Loop Terminating Adapter Unit		— —	78 mA (idle or busy)
1105E/F CO FX Reverse Battery Adapter Unit		45 mA (idle)	35 mA (idle)
		85 mA (busy)	50 mA (busy)
1106E/F Subscriber FX Reverse Battery Adapter Unit		45 mA (idle)	45 mA (idle)
		70 mA (busy)	35 mA (busy)
		95 mA (ring)	70 mA (ring)
37536 Baseband Amplifier Unit		140 mA	— —
46246 DC Converter Unit		— —	1.0 A
Physical Arrangement		Standard 483-mm (19") rack mounting, with shelf extending 127 mm (5") to the front and 178 mm (7") to the rear of mounting surface.	

Table 5.4-2 (continued)

Standard Rack Assemblies (See figure 5-1) (Optional Equipment Not Included)	Vertical Mtg. Spaces	Height mm (")	Weight (Approx.) kg (lb)
36200-01 12-channel, four-wire terminating equipment, and connectorized jackfield assembly	7	311 (12-1/4)	21.3 (47)
36200-02 24-channel, four-wire terminating equipment, and connectorized jackfield assembly	12	533 (21)	29.9 (66)
36200-03 36-channel, four-wire terminating equipment, and connectorized jackfield assembly	18	800 (31.5)	44.9 (99)
36200-05 60-channel, four-wire terminating equipment, and connectorized jackfield assembly	30	1334 (52-1/2)	102.5 (226)
36200-12 24-channel and connectorized jackfield assembly	8	356 (14)	20.9 (46)
36200-13 36-channel and connectorized jackfield assembly	12	533 (21)	31.8 (70)
36200-15 60-channel and connectorized jackfield assembly	20	889 (35)	61.7 (136)
36200-16 120-channel and connectorized jackfield assembly	40	1778 (70)	123.4 (272)
36200-25 60-channel, 11A signaling equipment, power filter and fuse panel, and connectorized jackfield assembly	40	1778 (70)	139.5 (307-1/2)

Environmental Conditions	
Temperature Range	0°C to 50°C (32°F to 122°F) operating —40°C to +65°C (—40°F to +149°F) shipping and storage
Maximum Relative Humidity	95% at 40°C (104°F) operating, shipping, and storage
Maximum Altitude	4572 m (15,000 feet) operating 15.24 km (50,000 feet) shipping

GTE Lenkurt may change performance specifications where necessary to meet industry requirements.

Source: GTE Practices, Section 342-361-112, Issue 2, May 1978.

Table 5.4-3

Technical Summary for the GTE Lenkurt 46A3 Multiplexer Equipment

Number of Channels	12 to 2400 (3600 in future), with conventional and DFSG (directly formed supergroup) channel equipment; 12 to 132 channels with DTL (direct-to-line) channel equipment.
Modulation	Single sideband, suppressed carrier
Coordination	End-to-end compatible with GTE Lenkurt 46A, Western Electric LMX, and CCITT systems without mastergroup equipment; end-to-end compatible with GTE Lenkurt 46A and Western Electric MMX-2R/C with mastergroup equipment.
Frequencies	
Voice	200/250 Hz to 3450 Hz
Basic Group*	60 kHz to 108 kHz
Basic Supergroup	312 kHz to 552 kHz
Basic Mastergroup	564 kHz to 3084 kHz (46A-U600)
Direct-to-Line Channels	12 kHz to 60 kHz (CCITT Group A)
	60 kHz to 300 kHz (Supergroup 1)
	312 kHz to 552 kHz (Supergroup 2)
Supergroups to Line	60 kHz to 2540 kHz (46A-600; CCITT)
	60 kHz to 4028 kHz (46A-960; CCITT)
	60 kHz to 2788 kHz (46A-600L; L600)
	564 kHz to 3084 kHz (46A-U600; U600)
Mastergroups to Line	564 kHz to 11,404 kHz (46A-MG; L4)
	564 kHz to 17,548 kHz (future)
Pilots	
Group	84.08 kHz, 92 kHz*, or 104.08 kHz
Supergroup	315.92 kHz, 411.92 kHz, or 547.92 kHz*
Mastergroup	2840 kHz
Line	60 kHz, 64 kHz, 308 kHz, 512 kHz, or 564 kHz
Levels and Impedances (at VF and HF Jacks)	
VF Mod Input	−16 dBm; 600 ohms
VF Dem Output	0 dBm to +10 dBm, adjustable; 600 ohms
DTL/DFSG HF Interface	Specified separately below
Group Mod Input*	−42 dBm, adjustable ±1 dB; 135 ohms
	−37 dBm, adjustable ±1 dB; 75 ohms
Group Dem Output*	−5 dBm, adjustable ±3 dB; 135 ohms
	−8 dBm, adjustable ±3 dB; 75 ohms
Supergroup Mod Input	−35 dBm or −25 dBm, adjustable ±1 dB; 75 ohms
Supergroup Dem Output	−30 dBm or −28 dBm, adjustable ±3 dB; 75 ohms
Mastergroup Mod Input	−21 dBm or −15 dBm, 75 ohms, for 46400/46401 shelf; −21 dBm, 75 ohms, for 46402 MG 3 shelf.
Mastergroup Dem Output	−15 dBm, −14 dBm, or −10.8 dBm, 75 ohms, for 46400/46401 shelf; −14 dBm, 75 ohms, for 46402 MG 3 shelf.
HF Line Transmit	
600 Chan Supergroup Eqpt	−50.4 dBm to −19.4 dBm; 75 ohms or 124 ohms
960 Chan Supergroup Eqpt	−53.8 dBm to −22.8 dBm; 75 ohms or 124 ohms (level range includes combining hybrid loss)
600 Chan Mastergroup 3 Eqpt	−5C.5 dBm to −25 dBm; 75 ohms or 124 ohms
2400 Chan Mastergroup Eqpt	−51.5 dBm to −20 dBm; 75 ohms or 124 ohms
HF Line Receive	
600 Chan Supergroup Eqpt	−35.7 dBm to −4.7 dBm; 75 ohms or 124 ohms
960 Chan Supergroup Eqpt	−32.4 dBm to −1.4 dBm; 75 ohms or 124 ohms (level range to combining hybrid input)
600 Chan Mastergroup 3 Eqpt	−36.5 dBm to −5.1 dBm; 75 ohms or 124 ohms
2400 Chan Mastergroup Eqpt	−36 dBm to −4.5 dBm; 75 ohms or 124 ohms
DTL HF Interface (12-552 kHz) w/o Line Interface Equipment	
HF Line Transmit	
12-Channel Shelf Terminal	−53 dBm to −21.5 dBm; 75 ohms
12-132 Channel Assembly	−50.5 dBm to −35 dBm; 75 ohms
HF Line Receive	
12-Channel Shelf Terminal	−51 dBm to −20.5 dBm; 75 ohms
12-132 Channel Assembly	−26 dBm to −10.5 dBm; 75 ohms

*Specification or option does not apply to DTL and DFSG channel equipment.

Table 5.4-3 (continued)

DFSG HF Interface (312-552 kHz)	
HF Transmit	−35 dBm, −31.8 dBm, −25 dBm, or −21.8 dBm; 75 ohms
HF Receive	−30 dBm or −28 dBm; 75 ohms
Pilot Levels	
Group Pilot	−20 dBm0
Supergroup Pilot	−20 dBm0
Mastergroup Pilot	−20 dBm0
Line Pilot	−10 dBm0 (46A coord) or −14 dBm0 (Bell coord)
Frequency Stability	
Master Oscillator	5 parts in 10^8 per 90-day period with 46710 Master Oscillator; 5 parts in 10^7 per 90-day period with 46711 Master Oscillator.
VF-to-VF Error	Zero error with synchronization; less than 1.25 Hz error in any channel through Mastergroup 4 in unsynchronized system using 46710 Master Oscillator; less than 0.6 Hz error in any channel through Supergroup 3 in unsynchronized system using 46711 Master Oscillator.
Phase Jitter	
VF Drop to VF Drop	3° peak-to-peak, all system arrangements
Carrier Leak Toward Line	
Channel	−38 dBm0 maximum; −45 dBm0 average
Group or Primary Group	−50 dBm0 maximum
Supergroup	−45 dBm0 maximum
Mastergroup	−35 dBm0 maximum
VF Drop Level Stability (Back-to-Back Terminals)	
VF Drop to VF Drop	±0.2 dB maximum mean variation ±0.7 dB maximum standard deviation with normal distribution in one month period

Channel Frequency Response (Gain Relative to 1000 Hz, Back-to-Back Terminals)

With 46110 Channel Unit (46A3)		With 46111 Channel Unit (46A6)	
250 Hz	−3.0 to +0.5 dB	200 Hz	−3.0 to +0.5 dB
400 Hz	−1.5 to +0.5 dB	300 Hz	−1.6 to +0.5 dB
600 Hz	−0.7 to +0.5 dB	600 Hz	−0.5 to +0.5 dB
3000 Hz	−0.7 to +0.5 dB	2800 Hz	−0.5 to +0.5 dB
3300 Hz	−1.5 to +0.5 dB	3450 Hz	−3.0 to +0.5 dB
3450 Hz	−3.0 to +0.5 dB		

Envelope Delay Distortion (Unequalized)		
VF to VF, Back-to-Back Terminals	<200 µs	1000 Hz to 2600 Hz
	<400 µs	800 Hz to 2800 Hz
	<750 µs	**600 Hz to 3200 Hz
	<1000 µs	**500 Hz to 3200 Hz
Envelope Delay Distortion With 46190 Channel Delay Equalizer		
VF to VF, Back-to-Back Terminals	<100 µs	1000 Hz to 2600 Hz
	<140 µs	800 Hz to 2800 Hz
	<165 µs	**600 Hz to 3200 Hz
	<180 µs	**500 Hz to 3200 Hz

Absolute Delay at Midband	
VF to VF, Back-to-Back Terminals	<1520 µs, unequalized <3720 µs, with equalizer
Harmonic Distortion	
VF to VF, Back-to-Back Terminals	1%, total (−40 dBm0)
Crosstalk Coupling Loss	>70 dB intelligible, measured between any two channels in the same group with a 0 dBm0, 1 kHz tone in the disturbing channel. >75 dB intelligible, measured between any two channels in different groups with a 0 dBm0, 1 kHz tone in the disturbing channel. >64 dB unintelligible, measured C-message weighted on either adjacent channel with a 0 dBm0 transmitter-weighted noise spectrum applied in the disturbing channel.

**The highpass filter used optionally in Channel 2, 5, or 7 will add 50 µs delay at 500 Hz and 600 Hz.

Table 5.4-3 (continued)

Sidetone Coupling Loss	
Near End	>65 dB, with hf transmit and receive terminated
Far End	>65 dB, with vf transmit and receive terminated
Net Loss Linearity	Net loss linearity of looped or end-to-end channels will be within ±0.3 dB of loss at −10 dBm0 over a level range of −30 to 0 dBm0.
Noise Performance (Back-to-Back Terminals)	
Idle Noise (Maximum)	C-Message Weighting
132-Channel DTL Terminal	13.0 dBrnc0 (20 pW)
600-Channel Terminal (w/o MG eqpt)	19.5 dBrnc0 (90 pW)
960-Channel Terminal (w/o MG eqpt)	20.9 dBrnc0 (122 pW)
600-Channel Terminal W/MG 3 Eqpt	20.0 dBrnc0 (100 pW)
600-2400 Channel Terminal W/MG Eqpt	20.4 dBrnc0 (110 pW)
Loaded Noise – CCITT Loading (−15 dBm0/chan)	
132-Channel DTL Terminal	15.1 dBrnc0 (32 pW)
600-Channel Terminal	20.2 dBrnc0 (104 pW)
960-Channel Terminal	21.5 dBrnc0 (140 pW)
600-Channel Terminal W/MG 3 Eqpt	21.9 dBrnc0 (154 pW)
600-2400 Channel Terminal W/MG Eqpt	21.3 dBrnc0 (134 pW)
Loaded Noise – 46A Loading	
132-Channel DTL Terminal, at −8 dBm0/chan	21.0 dBrnc0 (126 pW)
600-Channel Terminal, at −8 dBm0/chan	24.0 dBrnc0 (251 pW)
960-Channel Terminal, at −8 dBm0/chan	24.7 dBrnc0 (293 pW)
600-Channel Terminal W/MG 3 Eqpt, at −13 dBm0/chan	22.9 dBrnc0 (197 pW)
600-2400 Channel Terminal W/MG Eqpt, at −13 dBm0/chan	22.5 dBrnc0 (176 pW)
Voltage Requirements	−22 to −28 Vdc or −42 to −56 Vdc
Physical Arrangement	Standard 19" rack mounting, with shelf extending 5" to the front and 7" to the rear of mounting surface.
Standard Rack Assemblies	See figures 4-2, 4-3 and 4-4
Environmental Conditions	
Temperature Range	0°C to 50°C (32°F to 122°F) operating −40°C to +65°C (−40°F to +149°F) shipping and storage
Maximum Relative Humidity	95% at 40°C (104°F) operating, shipping and storage
Maximum Altitude	15,000 feet, operating 50,000 feet, shipping

GTE Lenkurt may change performance specifications where necessary to meet industry requirements.

Source: GTE Practices, Section 342-461-101, Issue 3, January 1976.

Since 8000 frames per second are transmitted, the transmission bit rate is

$$193 \times 8000 = 1{,}544{,}000 \text{ bps.}$$

The CEPT system is a 32-channel system where 30 channels transmit speech and two channels transmit signaling and synchronizing information. The speech signals are coded into an 8-bit word. A special word for synchronization is transmitted in the first slot of every second frame, while signaling information is coded into the 16th slot.

The AT&T D2 system is a 96-voice channel system made up of four groups of 24 voice channels each. Each group of 24 channels uses 8 bits to code each sample. The frame has a structure similar to the D1 system with $(8 \times 24 + 1)$ 193 bits per frame, except that all 8 bits are used for information coding with signaling transmitted through bit 8 of all channels only for every 6th frame. Using the D1 or D2 channel banks higher order PCM systems are derived. For example, four D2 channel banks are multiplexed into a 6.312 Mb/s bit stream using a M1-2 multiplexer. A higher order multiplexer M2-3 will output 45 Mb/s on a single transmission channel, while the M3-4 combines six 46.304 Mb/s into a single 274 Mb/s bit stream. AT&T defines its repeatered lines for transmission of PCM signals as T1 (at 1.544 Mb/s), T2 (at 6.312 Mb/s), T3 (at 46.304 Mb/s) and T4 (at 274 Mb/s).

Digital signals can be transmitted in either a neutral, polar or bipolar format. PCM signals transmitted on cable are in a bipolar format where alternate "1"s are coded as positive and negative, respectively, while "0"s are coded as absence of pulses. In such a situation, codes have been developed that are bipolar but have an N zeroes substitution called the BNZS code. For example, a B6ZS code substitutes a particular signal for a string of six "0"s.

5.4.1 Performance Characteristic of a TDM System

In PCM systems the equivalent to thermal noise is generated in the modulation-demodulation process. This is called quantizing distortion and has a similar effect at the receiver as thermal noise in FDM systems. Quantizing distortion is caused by the process of forming a PCM bit stream by coding sample values. Since a 7- or 8-bit code can at most provide 128 (2^7) or 255 (2^8)* distinct values, quantizing error is caused whenever a sample value falls within two discrete values represented by the PCM code. Quantizing distortion is the difference between the actual value of a given sample and its equivalent coded value. Quantizing noise is reduced by two methods; non-uniform quantizing and companding. Non-uniform quantizing is performed in the coding process by using finer quantum steps for signals with low amplitudes and larger quantum steps for the larger amplitude portion of a signal. For example, out of the 128 possible quantities, 20 could be assigned to voltage levels between 0.0 and 0.1 volts, 15 to voltage levels between 0.1 and 0.2 volts, 10 to voltage levels between 0.2 and 0.2 volts and so on. Companding is a form of compression of signals before the signals enter the coder. The coder then performs uniform coding on the compressed signal. At the received end expansion is carried out after decoding. Companding gives finer granularity to smaller amplitude signals. The compression and expansion functions are logarithmic and follow the "A" or the "μ" law which are plotted, respectively, as

$$Y = \frac{Ax}{(1 + \log A)} \qquad 0 \leq x \leq 1/A$$

$$Y = \frac{\log(1 + \mu x)}{\log(1 + \mu)} \qquad -1 \leq x \leq 1$$

The parameters "A" and "μ" determine the range over which the quality of a PCM signal, given by signal to distortion ratio, is comparatively constant. Also, higher values of these parameters cause finer granulation near low signal levels, which tends to reduce idle channel noise.

Gaussian noise present in a channel is important for the error performance of a TDM system. In a purely binary system a 20 dB signal-to-noise ratio will maintain an almost error-free performance.

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* The bit pattern with all '0's has a '1' inserted in the seventh bit position to avoid a code sequence with no transitions.

Another important performance limitation for a TDM system is "jitter". Jitter is caused by the movement of zero crossings of a signal from their expected time of occurrence. In long chains of regenerative repeaters offset pulses, intersymbol interference, and local clock threshold offset increases in RMS (root mean square) value as $N^{\frac{1}{2}}$, where N is the number of repeaters in the chain.

5.4.2 TDM Equipment Manufacturers and Models

Table 6 gives a list of TDM equipment models available on the market. Here again, actual system cost will depend on system specifications. We have attempted to list a few costs for budgetary estimates, but these should not be used as a basis for comparing different vendor models. For specific applications systems must be priced out separately by contacting the appropriate vendors. Table 7 is a list of some of the TDM equipment vendors. Table 8 is a typical specification sheet for the GTE Lenkurt model 9120A digital multiplexer.

Table 5.4-4

Time Division Multiplex Equipment

MANUFACTURER & MODEL NUMBER	DESCRIPTION	COMPATIBILITY	COST*
GTE Lenkurt 9120A digital multiplexer	Combines 2 or 4 nonsynchronous 1.544 Mb/s PCM (D1) bit streams into 6.3 Mb/s for transmission over GTE Microwave Radio, T2 repeatered lines	End to end compatible with Western Electric M1-2 system	$4,630
GTE Lenkurt 9122A asynchronous digital multiplexer	Combines 2 asynchronous 1.544 Mb/s PCM signals in a 3.152 Mb/s format for transmission over T1C-type lines retrofitted with GTE Lenkurt's duobinary repeaters	End to end compatible with Western Electric M1C multiplexer	
GTE Lenkurt 9002B PCM channel bank	Combines one to 24 voice channels on two cable pairs at a pulse rate of 1.544 Mb/s. Intended for inter-toll trunks with up to 200 tandem regeneration.	Compatible with Western Elec. D2 and D3 channel banks. Has available more than 30 types of plug-in channel signaling units to supply exchanges and subscriber services, as well as toll links.	24-channel shelf: $1240 with the common equipment plus $265 per four-wire channel.
GTE Lenkurt 910 PCM subscriber carrier system	One to 48 channels on four cable pairs at 1.544 Mb/s each 24-channel system	Special version of the 9002B D2 format PCM channel bank	

Table 5.4-4 (continued)

MANUFACTURER & MODEL NUMBER	DESCRIPTION	COMPATIBILITY	COST*
Aydin Vector DCB-T48 T-carrier channel bank	Permits transmission of 48 full duplex voice cirtuits via a T1 repeatered line. The 48 channels are converted into 32 kbps/channel and time division multiplexed into one Bell System compatible T1 (1.544 Mb/s) bit stream. When a 64 kbps channel is required, two 32 kbps cards are replaced by the single 64 kbps card.	Three different plug-in compatible codecs are available: a continuously variable slope delta modulation codec operating at 32 kbps; a variable quantum level PCM codec operating at 32 kbps; and a conventional 8-bit μ-law companded PCM codec operating at 64 kbps. Additionally, synchronous, 56 kbps digital ports can be provided in the place of two 32 kbps voice channels.	$20,000, using CVSD codecs and $25,000 using VQL PCM codec. For each CVSD codec replaced with a PCM codec, obtain approximately $100 credit.
Granger Associates TM7400 Transmultiplexer	Converts 24 TDM-PCM voice channels that conform to the D3 format at 1.544 Mb/s into two 12-channel FDM basic groups at 60 to 108 kHz. Also converts TDM signaling bits to FDM in-band 2600 Hz signaling tones translated to basic group frequencies.	PCM interface is compatible with standard AT&T D2, D3 format	$12,000 for 24 trunks

Table 5.4-4 (continued)

MANUFACTURER & MODEL NUMBER	DESCRIPTION	COMPATIBILITY	COST*
Cushman CE 1201 Digital Multiplexer	The multiplexer takes 12 asynchronous 1.544 Mb/s bipolar lines and converts them into a serial pulse train. The 12-port multiplexer system is essentially two independent 6-port multiplexer systems driven by a common clock. Data from the six line cards is interleaved with framing and control pulses to generate a 9.67 Mb/s data signal.	Interfaces with standard Western Electric T1 lines and is fully compatible with all DSX-1 requirements	$5000 for the shelf assembly plus $325 per T1 (1.544 Mb/s) line interface
Lynch B325 PCM channel banks	Operates over a T1-repeatered line to provide 24 two-way voice channels. Two B325 terminals with the addition of an optional D4 converter board provide 48 voice channels over a TIC repeatered line	Compatible with AT&T D3 and D4 format.	

*The costs quoted here are estimates given by vendors for certain individual equipment parts. These should not be used for comparative purposes. A budgetary estimate must be obtained from the vendor once a complete system is specified.

Table 5.4-5

List of TDM Manufacturers

GTE Lenkurt 1105 Old County Road San Carlos, CA 94070	(415) 595-3000
Aydin Vector Division P.O. Box 328 Newtown, PA 18940	(215) 968-4271
Farinon Electric 1691 Bayport Avenue San Carlos, CA 94070	(415) 592-4120
Cushman Electronics Inc. 2450 North First Street San Jose, CA 95131	(408) 263-8100
Lynch Communication Systems Inc. 204 Edison Way Reno, Nevada 89520	(702) 786-4020
Western Electric Company	(call local telephone company representative)

Table 5.4-6

Technical Summary for the GTE Lenkurt 9120A Digital Multiplexer

DS1 Interface		
Line rate	1.544 Mb/s ±130 ppm	
Line code	Bipolar	
Pulse amplitude, base-to-peak		
Multiplexer input (transmit)	2.0 to 3.3 volts	
Multiplexer output (receive)	6.0 volts ±10% into a shelf-mounted 6-dB pad or cable equalizer	
Pulse characteristics at DSX1		
Amplitude, base-to-peak	3.0 volts ±10%	
Width at 50% amplitude	324 ±30 nanoseconds	
Rise and decay time	Less than 80 nanoseconds between 10% and 90% amplitude	
Power ratio, positive to negative pulses	Less than 0.5 dB	
Line impedance	110 ohms ±5%, balanced	
Signal statistics	Average pulse density at least 1 in 8; not more than 15 consecutive 0's	
Maximum DS1 signal cable length, multiplexer to DSX1 cross-connect		
GTS-8507 (General Cable type 4162)	166 m (544 feet)	
GTS-8510 (General Cable type 4155) or ABAM	200 m (655 feet)	
Microwave Radio Interface	3.1 Mb/s	6.3 Mb/s
Bit rate	3.156 Mb/s ±30 ppm	6.312 Mb/s ±30 ppm
Code	Modified duobinary	Modified duobinary
Impedance	124 ohms ±5%, balanced	75 ohms, unbalanced
Return loss	26 dB minimum, 10 kHz to 1.5 MHz	23 dB minimum, 10 kHz to 1.5 MHz
Multiplexer output	1.0 volt peak-to-peak ±5%	1.0 volt peak-to-peak ±5%
Multiplexer input	1.0 volt peak-to-peak ±10%	1.0 volt peak-to-peak ±5%
Maximum out-of-band power in any 4-kHz band		
1.6 to 2.4 MHz	−48 dBm0	−51 dBm0
Above 2.4 MHz	−68 dBm0	−69 dBm0
Below 8 kHz	−50 dBm0	−66 dBm0
Maximum signal cable length, multiplexer to radio	15 m (50 ft) of General Cable type T-43M	1.8 m (6 ft) of RG-187/U Coax Cable
DS2 Interface, 6.3 Mb/s		
Line rate	6.312 Mb/s ±30 ppm	
Line code	Bipolar with six-zero substitution (B6ZS)	
Impedance	110 ohms ±5%, balanced	
Pulse amplitude, base-to-peak		
Multiplexer output (transmit)	2.1 volts ±10%, 50% duty cycle, into the line or a shelf-mounted lbo network	
Multiplexer input (receive)	0.3 to 2.3 volts	
Maximum signal cable length, multiplexer to DSX2		
GTS-8507 (General Cable type 4162)	265 m (870 feet)	
GTS-8510 (General Cable type 4155) or ABAM	305 m (1,000 feet)	
Maximum Error DS1 Rate per DS1	10^{-8} with two back-to-back multiplexers	
Alarms		
Functions monitored and alarmed at near end	Receive clock, synchronization, power, syndes overflow, and duobinary pattern violations (strap option for radio arrangements)	
Functions monitored at near end and alarmed at far end	Same as above except syndes overflow is a strap option	
Office alarm circuits		
Types	Audible and visual with form C relay dry contacts and audible ACO switch	
Contact rating	1 ampere maximum, noninductive	
Input Power		
24-volt option	22 to 28 volts at 2 amperes maximum	
48-volt option	44 to 56 volts at 1.2 amperes maximum	

Table 5.4-6 (continued)

Environment	
Ambient temperature range	0°C to 50°C (32°F to 122°F)
Maximum relative humidity	95% at 40°C (104°F)
Maximum operating altitude	4572 m (15,000 ft)
Physical Arrangement	
Rack mounting	Standard 483-mm (19-inches) rack; 305 mm (12 inches) maximum overall depth with 127 mm (5 inches) forward projection
Mounting spaces	Five spaces (four without jackfield)
Maximum weight	13.5 nm (29 pounds)

Equipment	Weight		Dimensions (H,W,D)	
	kg	Lbs	Millimetres	Inches
1157A —48V Power Supply	1.63	3.6	168 x 66 x 262	6.6 x 2.6 x 10.3
1157B —24V Power Supply	1.63	3.6	168 x 66 x 262	6.6 x 2.6 x 10.3
91488 Transmit Interface Unit (3.1-Mb/s radio)	0.36	0.8	175 x 36 x 262	6.9 x 1.4 x 10.3
91489 Receive Interface Unit (3.1-Mb/s radio)	0.41	0.9	175 x 36 x 262	6.9 x 1.4 x 10.3
91495-01 Transmit Interface Unit (6.3-Mb/s radio)	0.28	0.6	175 x 36 x 262	6.9 x 1.4 x 10.3
91496-01 Receive Interface Unit (6.3-Mb/s radio)	0.48	1.1	175 x 36 x 262	6.9 x 1.4 x 10.3
91960-01 Multiplex Equipment Shelf (without jackfield)	4.90 (9.53 maximum fully equipped)	10.8 (21 maximum fully equipped)	178 x 483 x 305	7 x 19 x 12
91960-02 Multiplex Equipment Shelf (with jackfield)	6.62 (11.34 maximum fully equipped)	14.6 (25 maximum fully equipped)	222 x 483 x 305	8.75 x 19 x 12
91961 Transmit Common Unit	0.23	0.5	175 x 36 x 262	6.9 x 1.4 x 10.3
91962 Receive Common Unit	0.27	0.6	175 x 36 x 262	6.9 x 1.4 x 10.3
91963 Alarm Unit	0.36	0.8	175 x 36 x 262	6.9 x 1.4 x 10.3
91964 Event Counter Unit	0.23	0.5	175 x 36 x 262	6.9 x 1.4 x 10.3
91965 Syndes Unit	0.32	0.7	175 x 36 x 262	6.9 x 1.4 x 10.3
91966 Transmit Interface Unit (6.3-Mb/s DS2)	0.27	0.6	175 x 36 x 262	6.9 x 1.4 x 10.3
91967 Receive Interface Unit (6.3-Mb/s DS2)	0.32	0.7	175 x 36 x 262	6.9 x 1.4 x 10.3

GTE Lenkurt may change performance specifications where necessary to meet industry requirements.

Source: GTE Practices, Section 342-911-105, Issue 3, November 1978.

5.5 SINGLE-CHANNEL -PER-CARRIER (SCPC) AND DEMAND ASSIGNMENT MULTIPLE ACCESS (DAMA) EQUIPMENT.

Single-channel-per-carrier (SCPC) communications by satellite utilize a separate transmit and receive carrier for each channel of information. This is significantly different from the Frequency Division Multiplex (FDM) technique which stacks many channels on a single carrier. By using SCPC, a lower value of transmitter power and a lower value of earth station G/T* are required for the transmission than in the FDM scheme. Also, power and bandwidth of the carriers can be saved when the channel is idle compared to the fixed-assigned FDM scheme, because the SCPC system allows the RF carrier to be idle or assigned to another user when a channel is not active. Further advantages of SCPC are flexibility in operation, in frequency assignment, and in growth due to increased demand. For example, in thin-route communications both the initial cost and the incremental cost for additional channels will be relatively low for SCPC schemes; it is relatively easy for the user to change the terminal capacity when the traffic demand changes. The modulating signals can be either analog or digital, and the modulation can be either FM or digital methods. Generally speaking, SCPC is the most cost-effective method of transmission for networks with small to medium traffic volume. It requires minimum equipment and can be quickly expanded simply by adding more channel units within the limitations of transponder bandwidth.

SCPC lends itself well to Demand Assignment Multiple Access (DAMA) techniques. In this mode of operation a common control network is used to set up matching channel frequency pairs according to the immediate traffic requirements at various stations, i.e., the control network selects necessary channel frequencies for each traffic requirement as it originates and arranges for the transmitting and desired receiving stations to adjust their transmitter and receiver accordingly. This provides a highly adaptive communications network by utilizing the channel frequencies, channel equipment, and signal powers much more efficiently than the preassigned operation.

The next section discusses the equipment for SCPC and DAMA systems in detail.

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* G/T = Antenna gain/system noise temperature. G/T is used as a figure of merit for satellite earth stations since a high G/T provides a better received signal-to-noise ratio. Increasing earth station G/T also results in increasing cost.

5.5.1 SCPC Equipment

The SCPC communication link includes the transmitting part of equipment in the transmitting station, the receiving part of equipment in the receiving station, and the satellite. Each station can have a number of channel units determined by the required capacity.

5.5.1.1 General Description

A SCPC terminal consists of a variety of equipment which provide the necessary functions including frequency translation, modulation, and demodulation, and the baseband signal processing. These functions perform a complete transformation between the input signals (usually voice, audio program, or data) and the RF signals. The equipment interface with input circuits on one side and the RF equipment including the high power amplifier (HPA) and low noise amplifier (LNA) on the other side.

SCPC equipment can be divided into two parts: the common equipment, and the channel equipment. A normal terminal requires only one set of common equipment to perform its function as long as the total number of channels provided by the terminal does not exceed some limit. Common equipment includes primarily the up/down converters and IF signal combining and distributing equipment. The channel equipment includes primarily the modulation, demodulation, and baseband signal processing equipment. A single set of channel equipment provides a single duplex (or two simplex) channels of communications. The channel equipment must be repeated for each desired duplex channel in the terminal. Each channel equipment has an independent modulation/demodulation unit; therefore, the channel equipment at a terminal can have a mixture of different types of signals; e.g., some channels provide voice and some channels provide data.

5.5.1.2 Common Equipment

On the receiving side, the received RF signal from the LNA is fed to the down converter which translates the received band of signals to IF frequencies. Image rejection filtering and IF gain are usually provided, and an AFC unit is commonly used to control the center frequency.

The output signal is then fed through an IF distribution network to the receive input of each of the channel units.

On the transmitting side, the output signals from each of the channel units are collected through the IF combining network first, and then fed to the up converter, which translates the IF frequency band to the RF band. Sufficient frequency accuracy is also necessary. The output of the up converter is then fed to the HPA.

A reference frequency unit is needed to generate necessary reference frequencies for the up/down converter and the modulator/demodulator in the channel equipment. The reference frequencies are usually phase-locked to a high stability source.

5.5.1.3 Channel Equipment

On the receiving side, the received signal from the common equipment is usually adjusted by an automatic gain control (AGC) to yield the desired carrier level, then fed to the demodulator. The demodulated signal is then passed through baseband signal processing circuitry which provides, according to the nature of the channel, suitable de-emphasis, expansion (if companding is used), filtering, and amplification. The resulting signal then goes to the output terminal.

On the transmitting side, again the input signals are first fed to the baseband processing circuitry providing suitable emphasis, compression (if companding is used), filtering and amplification. The output signal then goes to the modulator, and the modulated signal is then sent to the IF combining network of the common equipment.

5.5.1.4 Equipment Specifications and Costs

There are many specifications of an SCPC equipment that are important for users and designers. The signal types include voice, digital data, audio programs, etc. The modulation is basically FM or digital methods. Channel spacing determines the number of channels that can be accommodated in a transponder, usually ranging from 20 kHz to 300 kHz. Channel selection for most SCPC equipments are either preassigned or DAMA controlled. Emphasis and companding describe the characteristics of the emphasis and companding equipment that are used to improve the signal quality. Channel harmonic distortion, channel frequency response, and channel delay distortion describe the extent of various types of distortion the signals are allowed to suffer when passing through the equipment. Baseband interface gives the interface requirements of the equipment when connected with baseband circuitries, and RF interface provides the interface requirements of the equipment on the other side; i.e., when connected with the RF amplifiers. These interface requirements include frequency band, I/O impedance, return loss, and signal levels.

Prices for these equipments are essentially functions of the above specifications, specific options, quantities, etc. Generally speaking, the cost for common equipment is in the range of about $10,000 to $40,000, and the cost for channel units is in the range of about $2,000 to $5,000 each.

The specifications and costs of a few representative models made by some of the vendors are listed in Table 9. SCPC equipment vendors (with their addresses and telephone numbers) are listed in Table 10.

5.5.2 DAMA Equipment

The demand assignment multiple access (DAMA) equipment basically select the satellite frequencies for each call as it originates, and arranges for the calling station and called station to adjust transmitter and receiver frequencies accordingly to complete the call. There are currently different approaches to design such systems using different concepts. Some of these are more cost-effective for higher volumes of traffic, some are designed specially for thin-route communications, and some are more suitable for networks with fewer number of stations.

DAMA systems are usually divided into two categories: centralized and decentralized. Such a dichotomy is in fact a result of five major functions discussed below. A centralized system is one in which most of these five functions are done in a central station, and a decentralized system is one in which most of the functions are performed at each station itself.

Table 5.5-1

Specifications and Costs of Typical Example Models of SCPC Equipment

Company	SCIENTIFIC-ATLANTIC, INC.	COASTCOM	CALIFORNIA MICROWAVE, INC.
Model	Domestic Companded	411 A	SC 64
Signal Type	voice	audio program	voice
Modulation	FM	FM	FM
Channel Spacing	45 kHz	300 kHz	22.5, 30, or 45 kHz
Channel Select	Preassigned or DAMA	Preassigned or DAMA	Preassigned or DAMA
Emphasis	Dual break 600/5000 Hz	Dual break 600/5000 Hz	
Companding	CCITT G.162	CCITT G.162 (optional)	CCITT G.162
Channel Total Harmonic Distortion	2.5% (1000 Hz, 0 dBm0)	0.25% or 0.5% (companded) (200 Hz - 15 kHz) 0.5% or 1.0% (companded) (40 Hz - 200 Hz)	
Channel Freq. Response	±0.8 dB (400-3000 Hz) +1, -3 dB (300-3400 Hz)	±0.25 dB or ±0.5 dB (companded) (200 Hz-10 kHz) ±0.5 dB or ±1.0 dB (companded) (40 Hz-15 kHz)	±0.8 dB (400-3000 Hz) +0.8 dB - 3.0 dB (300-3400 Hz)
Channel Delay	200 μsec (600-3000 Hz) 300 μsec (500-3000 Hz)		200 μsec (600-3000 Hz) 300 μsec (500-3000 Hz)
Baseband Interface			
Baseband Freq.	300-3400 Hz	40-15,000 Hz	300-3400 Hz
I/O Impedance	600 ohms	600 ohms	600 ohms
Return Loss	20 dB	30 dB	24 dB ± 4 dB
Transmit Level	0 to -16 dBm		0 to -16 dBm
Receive Level	0 to +10 dBm	8 dBm (average)	0 to +10 dBm
RF Interface			
RF Frequency	3.7-4.2, 5.925-6.425 GHz	70 MHz	70 MHz
I/O Impedance	50 ohms	75 ohms	approx. 50 ohms
Return Loss	20 to 23 dB	26 dB	≥ 20 dB
Transmit Level	-25 to -31 dBm	-6 ±3 dBm	≤25 dBm
Receive Level	-69 to -82 dBm	-55 to -39 dBm	-72 to -82 dBm
Cost (budgetary, for planning purposes only)	For 2 channel units, \$59,400 each terminal (including up/down converter) Add'l channel units: \$2700 ea.	Receive channel, single frequency: \$1675 Additional channels: \$1300	For two channel units, \$39,000 to \$41,000 each terminal (including up/down converter) Add'l channel units: \$4000 ea.

Table 5.5-1 (continued)

Company	AYDIN MICROWAVE DIV.	ITT	HUGHES	DIGITAL COM. CORP.
Model	AM/DSCPC	ITTSPC	HS 732 A	STAC 5009, 5013 series
Signal Type	Digitized voice or data (to 2400 bps)	voice	voice	Digitized voice or data (to 2400 bps)
Modulation	QPSK	FM	FM	BPSK or QPSK
Channel Spacing	22.5 kHz	45 kHz	22.5,30,45,60 kHz	20 to 60 kHz
Channel Select	Preassigned or DAMA	Preassigned or DAMA	Preassigned or DAMA	Preassigned or DAMA
Emphasis		6 dB/octave (1000 Hz)		
Companding	CCITT G.162	CCITT G.162	CCITT G.162	
Channel Total Harmonic Distortion	5% (1000 Hz,-15 dBm0)	2.5%		
Channel Freq. Response	±1 dB (400-3000 Hz) +1 dB, -3 dB (300-3400 Hz)	±0.5 dB(300-3000 Hz) +0.5 dB, -0.8 dB (3000-3400 Hz)	±0.8 dB (400-3000 Hz) +1.0 dB, -3.0 dB (300-3400 Hz)	±1.0 dB (300-3400 Hz)
Channel Delay	1 μsec (600-2600 Hz) 1.5 μsec(300-2800 Hz)	200 μsec(600-3000 Hz) 300 μsec(500-3000 Hz)	200 μsec (600-3000 Hz) 300 μsec (500-3000 Hz)	300 μsec (500-3000 Hz)
Baseband Interface				
Baseband Freq.	300-3400 Hz	300-3400 Hz	300-3400 Hz	300-3400 Hz
I/O Impedance	600 ohms	600 ohms	600 ohms	600 ohms
Return Loss	20 dB	≥ 26 dB	20 dB	20 dB
Transmit Level	0 to -16 dBm	-4 to -16 dBm	0 to -16 dBm	0 to -16 dBm
Receive Level	7 dBm (average)	+4 to +7 dBm	0 to +10 dBm	0 to +10 dBm
RF Interface				
RF Frequency	70 MHz	70 MHz	70 MHz	70 MHz
I/O Impedance	50 to 75 ohms	50 ohms	50 ohms	50 ohms
Return Loss	≥ 20 dB	≥ 20 dB	≥ 20 dB	≥ 20 dB
Transmit Level	-10 dBm	-5 dBm (maximum)	-25 to -31 dBm	-15 dBm (nominal)
Receive Level	-85 to -25 dBm	-25 dBm (maximum)	-69 to -82 dBm	-35 dBm (nominal)
Cost (budgetary, for planning purposes only)			Not available	For 2 channel units + common equip, $56,000 ea. terminal; $16,000 per add'l 2-channel units + $10K for expansion rack for ea. 20 channels over 16. Total capacity: 96 channels.

Table 5.5-2

SCPC Equipment Vendors

SCIENTIFIC-ATLANTA, INC. 3845 Pleasantdale Road Atlanta, GA 30340	(404) 449-2000
COASTCOM 2312 Stanwell Drive Concord, CA 94520	(415) 825-7500
CALIFORNIA MICROWAVE, INC. 455 W. Maude Avenue Sunnyvale, CA 94086	(408) 732-4000
AYDIN MICROWAVE DIVISION 3180 Hanover Street Palo Alto, CA 94303	(415) 493-3900
ITT SPACE COMMUNICATIONS, INC. 69 Spring Street Ramsey, NJ 07446	(201) 825-1600
HUGHES AIRCRAFT COMPANY P.O. Box 9246 Los Angeles, CA 90009	(213) 648-2345
FAIRCHILD SPACE & ELECTRONICS CO. Germantown, MD 20767	(301) 428-6476
HARRIS CORPORATION P.O. Box 1700 Melbourne, FL 32901	(305) 725-2070
DIGITAL COMMUNICATIONS CORP. 19 Firstfield Road Gaithersburg, MD 20760	(301) 948-0850

5.5.2.1 Major Functions to be Performed

There are a number of functions to be performed by a DAMA system to control a SCPC network. The major ones are discussed here.

5.5.2.1.1 Station identification: determines from which station a call is originated and to which station the call is destined. Some systems use a translation table at a central station to identify the stations from signaling; some systems store a translation table at each station such that the origination station itself can find the identification number of the destination station and announce the call directly.

5.5.2.1.2 Frequency selection: selects a pair of unused channel frequencies to assign to the originated call. Some systems keep a continuously up-dated frequency table at a central station to perform this function, and some systems keep such a table at each station from which each station can select the appropriate frequency directly.

5.5.2.1.3 Frequency set-up arrangement: arranges the origination and destination stations to adjust their frequencies to those selected. Some systems announce the selected frequencies from a central station and the two stations involved then adjust accordingly. In other systems this is performed by the origination station itself.

5.5.2.1.4 Finished call clearing: Recovers the selected frequencies to idle status after the call is terminated. This is done in a central station for some systems, or in the two involved stations for some other systems.

5.5.2.1.5 Billing and maintenance information: Records and monitors the information for billing and maintenance. Again, this can be done either in a central station or in any station.

5.5.2.2 Common Signaling Channel (CSC).

In all DAMA systems designed so far, in order to perform the above major functions properly to control the network, a common signaling channel (CSC) is used to provide the necessary information: i.e., to carry the signaling information between stations before the call is established and after the call is terminated. All stations in the network listen to this channel and have access to the same information. In some of the designs the billing and maintenance information are also carried by this channel; in such cases the billing and maintenance can actually be controlled and monitored at any or all stations simply because all stations listen to this channel.

Different approaches are used to design the common signaling channel. Some systems (e.g., ITT) use preassigned TDMA; i.e., preassign specific time slots to each station. When a call is originated in a station, the station has to wait until the time slot assigned to it comes and then transmit the information. Some other systems (e.g., Harris Corp.) use the random access techniques; i.e., each station transmits its information whenever a call is originated. If two or more calls are originated within the same small period, the signaling information will collide and will have to be retransmitted using some prearranged scheme. In some other systems (e.g., GTE) the central computer requests information from each station in turn by sending a query signal.

5.5.2.3 Costs, Availability and Other Specifications.

Some companies produce and sell separate DAMA equipment while other companies only build DAMA equipment for their own SCPC satellite systems and sell the whole thing rather than separate equipment. The costs of separate DAMA equipment also varies significantly for different designs. For example, for decentralized DAMA, the cost of equipment at each station should not be too high, but for a centralized DAMA the cost of equipment at the central computer station is significantly higher.

There are many other specifications for DAMA equipment; e.g., the total number of stations that can be accommodated by the control system, the maximum total throughput of the network, the call set-up time, etc. But these specifications in general vary for different networks; i.e., depending upon the nature of the traffic, the call rate and call holding time, etc. They are difficult to specify for a single separate DAMA equipment without connecting a true network to it.

The major companies who are building DAMA equipment are listed in Table 11 (with addresses and phone numbers). Many other companies are considering and evaluating the applications of DAMA systems but are not currently building DAMA equipment; these include RCA, California Microwave, Inc., Scientific-Atlanta, Collins, etc. The currently available systems made by the major companies are listed in Table 12 with their general specifications.

5.6 FUTURE TRENDS.

Currently FDMA is the most common scheme for satellite access, but the trend towards TDMA will develop through cost reduction in digital logic, new coding techniques, and the continuing emphasis on digital terrestrial transmission. The simplicity and investment in current FDMA equipment will justify its continued application for some time. The trend towards TDMA is reinforced because of the satellite switched TDMA concept. Satellite switching will require an onboard processor at the satellite to rapidly connect bit streams over different spot beams in the same manner that a terrestrial switching office or PABX connects trunks. This will decouple the uplinks and downlinks and will increase usable satellite capacity by dynamically assigning the satellite's resources to meet demand. The most complicated on board processor will demodulate the RF carrier, decode it, extract routing information (or perform other forms of signal processing), then re-encode and remodulate the signal on the destination carrier.

Presently PCM coding techniques require almost 16 times the bandwidth required by a FDM system. This counter balances the improved noise performance of a PCM system. In the future we will see improved coding techniques which will result in fewer bits to encode a voice signal and the use of Digital Speech Interpolation techniques (DSI) to

Table 5.5-3

Major Vendors of DAMA Equipment

ITT Space Communications, Inc. 69 Spring Street Ramsey, NJ 07446	(201) 825-1600
GTE Waltham, MA 02154	(617) 890-9200
General Electric Co. P.O. Box 2500 Daytona Beach, FL 32015	(904) 258-2511
Har s Corporation P.O. Box 1700 Melbourne, FL 32901	(305) 725-2070
Hughes Aircraft Co. P.O. Box 92919 Los Angeles, CA 90009	(213) 648-8355
Ford Aerospace 3939 Fabian Way Palo Alto, CA 94306	(415) 494-7400

Table 5.5-4

Specifications and Costs of Typical Example Models of DAMA Equipment

Company	ITT Space Communications	GTE	General Electric Co.
Model	ITTSPC DAMA	Algeria System	GE DAMA
Centralization	Decentralized	Centralized	Centralized
Common Signaling Channel Format	TDMA preassigned at rate of 128 kbps	PSK at rate of 32 kpbs	QPSK at rate of 32 kbps "in-bound""outbound" polls
Content	All information needed in system except actual speech		All information needed in the system except actual speech
Station Identification	distributed translation table @ each station	translation table at central station	translation table at central station
Frequency Selection	distributed frequency table @ each station	frequency table at central station	frequency table at central station
Frequency Set-up Arrangement	origination station announces both transmit and receive frequencies to destination station	central computer announces selected frequencies to both origination and destination stations	central computer announces selected frequencies to both origination and destination stations
Billing and Maintenance Information	Can be available and monitored at any station.	Available and monitored at central computer.	Can be available and monitored at central computer or any other station, if desired.
Separate System Availability	yes	no	yes
Cost	$15,000 for common equip. including controller, CSC modem; $4500 for each channel unit	not available	$300,000 plus software cost for central station

Table 5.5-4 (continued)

Company	Harris Corporation	Hughes Aircraft Co.		Ford Aerospace
Model	Saudi Arabia & Sudan	HS 373	Indonesian	Ford Aerospace DAMA
Centralization	centralized	centralized	centralized	centralized
Common Signaling Channel: Format	random access in "inbound"; addressed messages in "outbound"	random access	sequential polling	random access, noncoherent modulation
Content		signaling information only; supervision information sent together w/speech		signaling information only; supervision information sent together with speech
Station Identification	translation table at central station	translation table at central station		translation table at central station
Frequency Selection	frequency table at central station	frequency table at central station		frequency table at central station
Frequency Set-up Arrangement	← Central computer announces selected frequencies to both origination and destination stations →			
Billing and Maintenance Information	Can be available and monitored at central computer or any other station, if desired	Available and monitored at central computer only		Available and monitored at central computer only
Separate System Availability	probably not	no	probably not	probably not
Cost		not available		

process PCM bit streams. DSI techniques make use of the low speech activity on incoming channels to interpolate speech spurts on a smaller number of channels.

For domestic systems and through-route telephony applications, we see continued application of SCPC with demand assigned features. Demand assigned TDMA will grow as component costs decrease.